Journal of Experimental Psychology:
Learning, Memory, and Cognition
1991, Vol. 17, No. 5, 940–953

0278-7393/91/$3.00

Mental Models and the Fan Effect

Gabriel A. Radvansky and Rose T. Zacks
Michigan State University

Explanations of data from fan effect experiments have been based on propositional network models. This article presents findings not readily predicted by such models. In particular, in three experiments we found that, during a speeded-recognition test, subjects retrieved facts about several objects associated with a single location faster than facts about several locations associated with a single object. Indeed, there was no fan effect in the former case despite the fact that there were an equivalent number of associations among concepts in both conditions. We suggest that such data are consistent with a mental model representational account.

A great deal of research in cognitive psychology aims to elucidate the nature of the mental representation used to perform various mental tasks. Often certain tasks are put forth as the source of evidence for a particular form of mental representation. A case in point is the fan effect paradigm (Anderson, 1974), which has been used to promote a propositional network form of representation, especially the ACT model (Anderson, 1974, 1983). The fan effect is an increase in retrieval time or error rate (e.g., on a recognition test of specific facts) accompanying an increase in the number of newly learned associations for a concept. In this article, we present data from three fan effect experiments as the initial part of an attempt to discover whether a mental model view (Johnson-Laird, 1983) may provide a description of certain aspects of fan effect performance.

The logic of the present research is introduced through some examples of the materials used in this research:

1. The cola machine is in the hotel.
2. The cola machine is in the public library.
3. The cola machine is in the high school.
4. The display case is in the city hall.
5. The potted palm is in the city hall.
6. The broken window is in the city hall.
7. The welcome mat is in the barber shop.

In this set of sentences three distinct cases arise. In the first case, Sentences 1 to 3 share the concept cola machine. In the second case, Sentences 4 to 6 share the concept city hall. In Sentence 7, there is only one association for both the subject and predicate. In all of the experiments, subjects first memorize a list of such facts and then are given a speeded-recognition test for those facts.

Propositional Networks and the Fan Effect

According to ACT (Anderson, 1974, 1983), information is structured in memory as a set of nodes and links that make up a network. The nodes of the network represent the concepts in memory, and the links represent the associations between these concepts. Each concept is represented by only a single node in the memory network. Additionally, in typical fan effect experiments, the preexperimental associations are ignored.

A memory probe causes the appropriate nodes of the network to become activated. This activation then spreads along the links emanating from the activated concepts either until the two spreads of activation intersect or until an appropriate amount of time has passed (Anderson, 1983). If the probe were Sentence 7, activation would only have to spread along a single associative link. If the probe were any of Sentences 1 to 6, activation would have to be divided equally among three associations. A larger number of links results in a finer division of activation causing the retrieval process to proceed more slowly.

For the present purpose, the most notable aspect of the ACT model is that it predicts an equal fan effect for Cases 1 and 2 where there are an equal number of associations. In the first case, there are three locations associated with the cola machine concept, and in the second case there are three objects associated with the city hall concept.

Mental Models and the Fan Effect

Finding a fan effect in conditions analogous to Case 1 but not Case 2 suggests that the propositional network view does not completely characterize the mental representation of the studied facts. Instead a complete account of fan effect data may require incorporating the notion of mental models (Johnson-Laird, 1983). This article explores this possibility.

Although the notion of a mental model is not fully developed and is sometimes vague (cf. Glenberg, Meyer, & Lindem, 1987), there are aspects of mental models that are sufficiently clear for specific predictions to be made. An important char-

Part of this research was presented at the 1989 meeting of the Psychonomic Society in Atlanta and at the 1990 meeting of the Midwestern Psychological Association in Chicago. This research was supported in part by National Institute on Aging Grant AGO 4306 to Rose T. Zacks and L. Hasher.

We thank Barbara Abbott, Tom Carr, Linda Gerard, Lynn Hasher, David Irwin, Michael McCloskey, and an anonymous reviewer for their helpful comments. We also thank Beth Chittenden, Roderick McFarland, and Heather Oonk for their assistance in the data collection.

Correspondence concerning this article should be addressed to Gabriel A. Radvansky or Rose T. Zacks, Department of Psychology, Michigan State University, East Lansing, Michigan 48824-1117.

acteristic of mental models for the present studies is that each presents a specific situation (Johnson-Laird, 1983). A situational representation is assumed to derive from the functional relationships between elements in the real world (e.g., a cola machine is related to a hotel in that the cola machine is in it). When a fact about a new situation is learned, a representation is constructed of the described situation. Subsequent information is then integrated into that representation if it is congruent with the portrayed situation based on a subject's world knowledge. If the new information is not congruent, then a new mental model is constructed.

With the present materials, different situations are assumed to derive from the use of different locations across facts. In the real world, an object cannot be in more than one place at once, nor does an object typically move from place to place. However, several objects can occupy the same location (if large enough) at one time. Therefore, in this case, location can be used as the basis for defining different situations. Sentences 1 to 3 may easily be conceived of as describing different situations because the cola machine is in different places (the hotel, the public library, and the high school). Consequently, these three facts will result in the construction of three separate mental models. We refer to such cases as multiple location (ML) conditions. Alternatively, Sentences 4 to 6 may easily be conceived of as describing a single situation, namely the state of affairs in which the display case, the potted palm, and the broken window are in the city hall. In this condition a single mental model is constructed through the integration of these three idea units around the location that contains the objects. We refer to such cases as single location (SL) conditions.[1]

The idea that subjects integrate related information into a single mental representation is not new (e.g., Bransford & Franks, 1971). What is new in the present article are the suggestions that situation-based mental models determine how facts will be integrated, and that this notion can be applied to the fan effect. We suggest that it is the number of mental models and not the number of associations involving a concept that determines when a fan effect will occur.

Each mental model is stored in long-term memory as a separate unit. Fact retrieval involves selection of the appropriate mental model and verification that its contents match (or do not match) the probe. The fan effect arises from the interference caused by related (through a shared concept) but irrelevant mental models hampering the selection of the correct one during the retrieval process. The more interfering mental models there are, the longer the retrieval time. The precise nature of this slowdown is unclear at this point. The details of the retrieval process in a mental model view have not been worked out completely. We offer the following as a set of working assumptions to permit initial tests of the mental model view.

In an SL condition, all of the facts associated with a location are encoded into a single representation. During retrieval, this is the only representation that needs to be accessed. There are no interfering mental models. Any interference that occurs in this condition is due to irrelevant objects also within the mental model. This within-model interference is believed to be minimal for the present sets of materials because the mental models created are relatively simplistic, and the retrieval of the facts from within a mental model is well practiced.

In an ML condition, by contrast, a separate mental model exists for each location the object is associated with. These additional mental models interfere with the retrieval of the appropriate one, thereby slowing retrieval. Greater numbers of additional mental models interfere more, thus generating the fan effect. Consequently, the interference generated during mental model retrieval from competing models (ML condition) is assumed to be greater than any interference that may be encountered while a single model is searched within working memory (SL condition). Therefore, the prediction is that retrieval in the SL condition will be faster than in the ML condition. Additionally, the SL condition will show a smaller fan effect than the ML condition, or the effect will be absent. Like the standard fan effect, these predictions hold for the verification of both studied and nonstudied probes. We refer to the effect on retrieval of the presumed organization of information in terms of the situations described as the situation effect. After presentation of the results of three experiments that support the mental model view, we consider the ability of this view to handle previous fan effect data, including other findings of reduced fan effects.

The comparison between the SL and ML conditions illustrated here is similar to Moeser's (1979) integration versus independence distinction of information storage. She found that if a set of facts can be easily integrated into a single representation, then no fan effect is found. However, if the same information is stored independently in separate representations, then a fan effect is found. Relative to the present experiments, the primary differences in Moeser's study are the stimulus materials and the procedure. The integrative materials used by Moeser could all be grouped in only one way, whereas the materials in the present experiments had alternative groupings. Additionally, Moeser found integrated storage when related facts were presented contiguously and independent storage when related facts were presented noncontiguously, whereas integration of the facts in the present experiments is sought when the facts are presented noncontiguously.

Experimental Methodology

The present experiments use the basic fan paradigm methodology (e.g., Anderson, 1974). In addition to examining the effect on retrieval time of different levels of fan (the comparison of interest in previous research), the experiments compare SL and ML conditions at the same levels of fan. Addressing the problem from a propositional network perspective predicts no difference between SL and ML conditions, only increased retrieval time with increased fan. A mental model view, by contrast, predicts the situation effect.

[1] It should be noted that although location does provide the basis for organizing a mental model in the present set of materials, in other cases it may not. We have data from similar experiments using sentences in which people and locations are used. In these experiments location was not the clear basis for organizing the mental model. These experiments are described in more detail later here.

The experiments share a common methodology, which is described first followed by the results of various baseline measures from all of the experiments.

General Methods

Subjects

All of the subjects were recruited from the Michigan State University subject pool and were native speakers of English. Subjects were given class credit for their participation except for those in the 1,000-ms sentence onset asynchrony (SOA) group of Experiment 3, who were paid $10 each.

Materials

The sentences were created by randomly pairing an object and a location. The objects were not intuitively preassociated with the location. The objects actually used in the experiments were described in two or three words, and the entire phrase ranged from 8 to 16 letters in length ($M = 11.9$). The locations were described in one, two, or three words, and the entire phrase ranged from 5 to 15 letters in length ($M = 11.1$; see Table 1 for a listing of all of the objects and locations).

Experiments 1 and 3 used sentences in which both the object and location served as the syntactic subject of the study sentences. To ensure that all of the materials used were sensible in both sentence forms, a normative study was conducted in which 50 subjects rated sentences for sensibility. These subjects did not participate in any other portion of these experiments.

In the norming study, the sentences included all possible paired combinations of 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*." This generation procedure produced a list of 800 sentences. These sentences were then randomly assigned to 1 of 10 lists; the only constraint was that each list contained equal numbers of each sentence type. 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 encourage subjects to attend more fully to the task. A 5-point rating scale was used ranging from *sensible* (1) to *not sensible* (5). 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 because these were believed to be sensible enough that subjects would incur no difficulty in comprehending them. Because some objects or locations were in a large number of sentences that were rated as being nonsensical, those sentences containing the 6 worst objects and locations were dropped from the remaining set, leaving 14 objects and locations that were used exhaustively. This procedure generated a list of 375 possible sentences. From this list of possible sentences, a unique list was generated for each subject in each experiment.

The construction of the present materials differed only slightly from that used in Anderson's (1974) original experiment. First, the largest fan level was four instead of three. Second, objects were used in the sentences rather than people. Third, the sentences used a definite rather than an indefinite article for the sentence subject to encourage subjects to treat each instance of an object or location as the same instance across sentences when it was repeated within a list. In a propositional network, this would promote the use of a single node for each concept. Fourth, the combinations of object and location fans tested in the recognition tests of these studies

Table 1
Design Used for Combining Subjects and Predicates in the Generation of the Study Lists

Object fan	Location fan 1	2	3	4
1	aA	bB	cC	dD
	hH	iI	jJ	kK
2	eE			eD
	lL			lK
3	fF		fJ	fD
	mM		mC	mK
4	gG	gB	gC	gD
	nN	nI	nJ	nK

Objects (lowercase letters)		Locations (uppercase letters)	
fire extinguisher	display case	hotel	community center
digital wall clock	broken window	airport	car dealership
welcome mat	revolving door	dry cleaners	ice cream parlor
travel poster	potted palm	barber shop	public library
pay phone	cola machine	city hall	office building
ceiling fan	wire wastebasket	laundromat	cocktail lounge
oak counter	bulletin board	high school	movie theatre

Note. In the location–subject conditions of Experiments 1 and 3, the order of the object and location terms were reversed.

were those involving either a single object associated with one to four locations or a single location associated with one to four objects. These combinations were selected to reflect a pure effect of either location fan or object fan (no combinations of multiple locations with multiple objects were tested). This allowed for a direct comparison of the SL and ML conditions.[2] The study lists did contain additional (but untested) sentences in conditions involving multiple objects in association with multiple locations. These sentences were included to create the appropriate number of associations for the test sentences without resulting in excessively large study lists. Table 1 presents the design used for pairing objects with locations. The lowercase letters indicate objects, and the uppercase letters indicate locations. Note that each object and location was repeated one to four times in the list, and that each object and location could appear anywhere within the design. Across subjects, different objects served as specific a–n items and different locations served as specific A–N items.

Table 2
Means and Standard Deviations (in Parentheses) of Wechsler Adult Intelligence Scale-Revised (WAIS-R) Vocabulary Test Scores, Number of Cycles Through Study–Test, and Number of Errors on Posttest

Factor	WAIS	No. cycles	Posttest (%)
Experiment 1			
Object–subject	46.8 (6.1)	4.3 (0.8)	0.00 (0.00)
Location–subject	44.5 (7.0)	4.9 (1.3)	0.34 (1.90)
Mean	45.6 (6.5)	4.6 (1.1)	0.34 (1.49)
Experiment 2			
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)
Mean	43.2 (6.4)	5.2 (1.1)	0.19 (1.45)
Experiment 3			
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)
1,000-ms SOA	50.3 (7.4)	4.8 (1.0)	0.88 (1.24)
Mean	48.4 (7.0)	4.7 (1.1)	0.80 (1.18)

Note. SOA = sentence onset asynchrony.

Procedure

Subjects were tested individually in a single session lasting approximately 1 1/2 to 2 hr. At the beginning of the procedure, each subject was administered the vocabulary section of the Wechsler Adult Intelligence Scale-Revised (WAIS-R) to detect any subjects low in verbal ability who might subsequently have difficulty because of the verbal nature of the materials. The designated cutoff was a score of 30 of a possible 70.

Subjects were first presented with study lists of 26 sentences with the instruction to memorize them as efficiently as possible (except for Experiment 2 where instructions were manipulated). The sentences were displayed one at a time for 7 s 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.

Each subject learned a different set of study sentences. A study–test procedure was used in which, after going through the entire list of sentences in random order, the subjects were presented with a series of test questions (also in random order). The questions were of the form "What is in the *location*?" or "Where is the *object*?" for each location and object, respectively. This study–test procedure was repeated until the subject was able to answer all of the test questions correctly twice in a row. This ensured that the subjects had memorized and could retrieve the entire list. A different random order was used for the presentation of each study and test trial.

The subjects were then given a speeded-recognition test. A studied fact was indicated by pressing a game paddle button held in the right hand, and a nonstudied fact was indicated by pressing one held in the left hand. 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 the subjects had to press the appropriate button. The studied probes in the recognition test were sentences from the study list, with two sentences per SL–ML condition at every fan level. The nonstudied probes were re-pairings of objects and locations from within the same cell. For example, if the two studied sentences from within a cell were Sentences 8 and 9, the nonstudied sentences would be 10 and 11:

8. The ceiling fan is in the airport.
9. The fire extinguisher is in the laundromat.
10. The ceiling fan is in the laundromat.
11. The fire extinguisher is in the airport.

The order of probe presentation was random. The computer recorded reaction times (RTs) and error rates.

An arbitrary cutoff of 10% errors on the recognition test was established. Subjects exceeding this cutoff were replaced. Subjects received feedback immediately after a trial if the response was incorrect. The feedback (presented for 500 ms) consisted of the presentation of a line that read either "*Error* sentence studied" or "*Error* sentence not studied," whichever was appropriate. For purposes of analysis, errors included not only incorrect responses, but also trials for which the RTs were shorter than 500 ms or longer than 10,000 ms. At the end of the recognition test, subjects were presented with a posttest composed of the questions used in the list-learning period.

General Results

The means and standard deviations for the WAIS-R vocabulary test, number of study–test cycles required to learn the list, and number of errors on the posttest are presented in Table 2. None of the between-groups differences involving these measures were significant. The WAIS-R vocabulary scores are typical for students at Michigan State University. The minimal variation in the number of cycles needed to

[2] According to the *min* effect described by Anderson (1976), when a concept has only a single association, as in both the SL and ML conditions, there is a potential for a reduced or absent fan effect. However, even with the min effect, the propositional network view does not predict a difference in the size of the SL and ML fans.

memorize the lists indicates that the subjects were approximately equal in their memorization skills. The small number of errors on the posttest indicates that the subjects were able to accurately retain all of the information throughout the recognition test. These data demonstrate uniformity across studies and conditions, but provide no further information regarding questions of interest and are not discussed again in this article.

Before turning to the individual experiments, one further issue needs clarification concerning the RT data (the primary dependent measure). This issue is the statistical approach used to test the mental model prediction for the reduced (perhaps to zero) fan effect in the SL compared with the ML condition. Various forms of statistical support can be garnered for this prediction. First is the main effect of location condition (SL–ML difference) in a Location × Fan analysis of variance (ANOVA). A finding of significantly longer RTs in the ML than in the SL condition is consistent with the notion of greater interference from irrelevant mental models in the former condition. This main effect was significant in all three experiments.

A second potential source of support for the mental model view is the Location × Fan interaction. In particular, a significant interaction reflecting a greater increase in RT with increasing fan in the ML than in the SL condition would be strong support for the mental model position. Although all three experiments show the expected trend, the interaction was significant only in Experiments 2 and 3. The failure to obtain a significant interaction in Experiment 1 is probably due to a flaw in our design of the studies. Specifically, we did not take into account the fact that the SL and ML conditions share the cell in which both object and location have a fan level of 1 (e.g., Sentence 7). Unfortunately, there were too few items in this cell to "divide" them between the SL and ML conditions, and it had to be dropped from the Location × Fan analyses. Because there is a large increase in RT from Fan Level 1 to Fan Level 2 in the ML condition (e.g., see Figure 1 for the Experiment 1 data), removal of the Fan Level 1 data works against a significant interaction. The different outcomes for Experiment 1 versus Experiments 2 and 3 are in part due to a larger total number of subjects in the latter experiments with a concomitant increase in power. The result of an alternative, although not ideal, approach is reported for Experiment 1. Specifically, an orthogonal comparison analysis was performed in which the mean RT of Fan Levels 2 to 4 for each of the SL and ML conditions was compared with the mean RT of the Fan Level 1 cell. This contrast was significant for the ML but not the SL condition, showing that higher fan levels are associated with longer RTs in the former case but not in the latter.

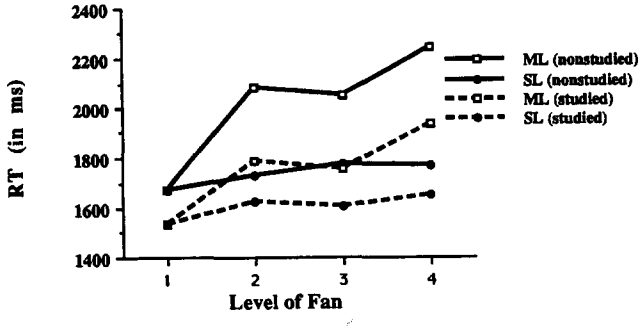

Figure 1. Situation effect for studied and nonstudied sentences for Experiment 1. (RT = reaction time; ML = multiple-location condition; SL = single-location condition.)

Experiment 1 demonstrated the presence of the situation effect with two differing syntactic forms for the facts. Experiment 2 investigated the effects of varied instructions on the situation effect. Finally, Experiment 3 showed how different cue types affect the situation effect based on the notion that the mental models of the facts are organized by location and are stored as separate units.

Experiment 1

In this study, locations served as the grammatical subject of the sentences for half of the participants and as the prepositional phrase for the remaining participants. This was done to demonstrate that the situation effect, if found, is not limited to a particular type of memorized sentences (e.g., location concept in the predicate position).

Method

Subjects. Thirty-two individuals were tested. Five additional subjects were replaced, 3 for exceeding the cutoff for errors on the recognition test and the other 2 for not meeting the criterion on the vocabulary test.

Procedure. Subjects were given the study–test procedure as described previously, and were then given a recognition test on reaching the memorization criterion. Subjects were divided into two groups. One group received object–subject sentences (OS) and the other group received location–subject sentences (LS). During the recognition test, there were four presentations of each probe yielding a total of 112 trials. Halfway through this test, a break occurred providing a subject-paced rest period. The posttest was composed of questions used in the list-learning period and followed the recognition test.

Results

Studied–nonstudied probe differences and fan effect. The RT data were submitted to a 2 (sentence type) × 2 (studied–nonstudied) × 4 (Fan Levels 1–4) mixed ANOVA; the first variable was between subjects. Unless noted otherwise, the level of significance for all statistical measures was set at $p < .05$. Subjects were quicker to decide that a probe was a studied sentence as opposed to a nonstudied one, $F(1, 30) = 19.15$, $MS_e = 126360$. Subjects also showed a fan effect, $F(3, 90) = 7.61$, $MS_e = 128586$. Neuman-Keuls tests showed, however, that only the Fan Level 1 RTs were faster than the RTs in the other conditions.

Situation effect. The RT results pertaining to the situation effect are summarized in Figure 1. As can be readily seen, the ML condition produced longer average RTs and somewhat steeper slopes as a function of fan level than the SL condition. The reliability of these trends was evaluated by a 2 (sentence type) × 2 (studied–nonstudied) × 2 (SL–ML) × 3 (Fan Levels 2–4) mixed ANOVA. The SL–ML difference was significant,

$F(1, 30) = 37.29$, $MS_e = 209223$. There was also a marginally significant interaction of situation effect with studied–nonstudied probe decisions, $F(1, 30) = 3.93$, $p < .06$, $MS_e = 182860$. The SL–ML difference for nonstudied decisions was larger than that for studied decisions.

The Location × Fan interaction was not significant. However, orthogonal comparisons showed that the average RT for Fan Levels 2 to 4 significantly differed from Fan Level 1 for the ML condition, $F(2, 30) = 11.65$, $MS_e = 1714684$, but not for the SL condition ($p > .20$). Additionally, Neuman-Keuls tests showed that whereas the SL RTs did not differ from one another, in the ML condition there was a significant difference between the Fan Level 3 and Fan Level 4 probe RTs. These last two results are consistent with the prediction of greater retrieval time increases with increasing fan for the ML condition compared with the SL condition.

Sentence subject type. The LS and OS conditions did not differ ($F < 1$). The fan effect within each of the two conditions was significant, $F(3, 45) = 4.84$, $MS_e = 61837$ for OS and $F(3, 45) = 3.25$, $MS_e = 66749$ for LS, as was the SL–ML difference, $F(1, 15) = 15.34$, $MS_e = 119524$ and $F(1, 15) = 22.37$, $MS_e = 92601$ for OS and LS respectively (see Figure 2). Neuman-Keuls tests of fan-level differences performed separately on the OS and LS data produced results similar to those for combined sentence type RTs. In general then, the grammatical form of the sentences appears to have had little bearing on the way facts were stored and retrieved.

Errors. The mean percentage of errors on the decision trials was 3.1% ($SD = 2.2$). There was a marginally significant fan effect, $F(3, 90) = 2.52$, $p < .07$, $MS_e = 37$. The percentage of errors increased with increasing fan. The means were 1.8, 2.8, 3.1, and 4.7% for Fan Levels 1 to 4, respectively. There was also a significant interaction of studied–nonstudied decisions with fan, $F(3, 90) = 2.75$, $MS_e = 33$. The fan effect was significant for the nonstudied probes, $F(3, 90) = 4.03$, $MS_e = 40$, but not for the studied probes, $F < 1$. Also there were more errors in the ML conditions ($M = 4.9\%$) than in the SL conditions ($M = 2.2\%$), $F(1, 30) = 9.44$, $MS_e = 72$. 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.

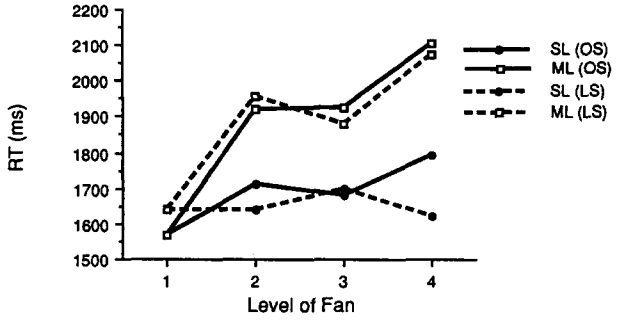

Figure 2. Comparison of the situation effect for object–subject (OS) and location–subject (LS) conditions for Experiment 1. (RT = reaction time; SL = single-location condition; ML = multiple-location condition.)

Discussion

The results of Experiment 1 suggest the existence of the situation effect. In addition, this experiment provided evidence that this effect is not restricted to a single syntactic structure because the same pattern of retrieval times was found when the location served as the syntactic subject of the sentences as when it served as the prepositional phrase.

The results are not predicted by propositional network theory. Although the fan effect itself is explained quite adequately, the situation effect is not derivable from such a theory at present. By contrast, the mental model theory provides a more straightforward account of the situation effect. Information that is consistent with a single situation, such as the state of affairs of several objects occupying a single location, is integrated into a single mental model representation. This integration allows for an attenuation of the fan effect.

Experiment 2

This study was devised to assess whether the situational organization is easily altered by instructions. That is, the question asked was whether subjects can organize their representations around objects rather than locations, reversing the pattern of retrieval times found in Experiment 1. The experimental procedure was identical to the previous experiment except that the subjects were given specific instructions on the method by which they should organize the facts in memory as they studied the list.

Subjects were divided into three groups—location, object, and neutral group—and each was instructed to memorize the list in a different manner. The location group was instructed to group the items in terms of the locations. The object group was instructed to group information in terms of the objects. The neutral group was told only to memorize the sentences as efficiently as possible with no suggestion for organizing the facts.

Assuming that the primary representations used with the present materials are mental models, two results were expected. First, the location group should not differ from either the neutral group or the data from the previous experiment in showing the situation effect. If location is the preferred basis of organization, the neutral group, given a choice of organizing on the basis of either location or object, will select location. Second, to the extent that the instructions have any effect, the location and neutral groups may show a greater situation effect than the object group. However, the object group will not show a reversal of the previously obtained situation effect resulting from an object-grouping strategy because different objects do not imply different situations.

Method

Subjects. Seventy-two subjects were tested, 24 in each instruction group. Two additional subjects were replaced for failing to meet the criterion on the vocabulary test.

Procedure. This experiment used the normed sentences of the form "The *object* is in the *location*." The procedure was identical to the previous experiment with the exception

of the memorization instructions. Before memorizing the sentences, the subjects in the location and object groups were instructed to "try to organize these facts in your mind in terms of the locations (objects)." Subjects were also reminded of the memorization strategy at the beginning of each study–test cycle as they learned the sentences. At the end of the experiment, the subjects were asked two or three questions: (a) "When an object was associated with multiple locations, did you consider it to be the same or different instances of the object for each of the locations?" (b) "When a location was associated with multiple objects, did you consider it to be the same or different instances of the location for each of the objects?" (c) "Did you follow the memorization strategy instructions during the study–test portion of the experiment?" (The neutral group was not asked this question.) The first question is referred to as the object question, the second as the location question, and the third as the instructions question.

Results

Studied–nonstudied probe differences and fan effect. The RT data were submitted to a 3 (instruction type) × 2 (studied–nonstudied) × 4 (Fan Levels 1–4) mixed ANOVA; the first variable was between subjects. Studied sentences were recognized more rapidly than nonstudied sentences, $F(1, 69) = 114.60$, $MS_e = 29907$. Subjects again showed the classic fan effect, $F(3, 207) = 22.85$, $MS_e = 58911$. Neuman-Keuls tests revealed that the retrieval times increased with each increase in fan level except between Fan Levels 3 and 4. There was an interaction of fan and studied–nonstudied decisions, $F(3, 207) = 8.97$, $MS_e = 23216$. The fan effect was larger for nonstudied probe decisions than for studied probe decisions.

Situation effect. The RT data were also submitted to a 3 (instruction type) × 2 (studied–nonstudied) × 2 (SL–ML difference) × 3 (Fan Levels 2–4) mixed ANOVA. Once again, the ML condition produced longer RTs than the SL condition as shown in Figure 3. This SL–ML difference was significant, $F(1, 69) = 132.82$, $MS_e = 143980$.

There were two significant interactions involving the location variable. The first was with the studied–nonstudied factor, $F(1, 69) = 13.76$, $MS_e = 53466$. The SL–ML difference

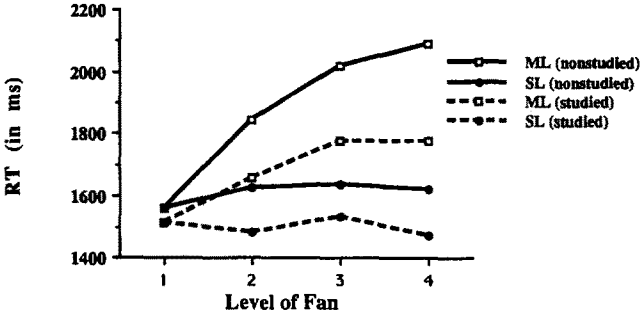

Figure 3. Situation effect for studied and nonstudied sentences for Experiment 2. (RT = reaction time; ML = multiple-location condition; SL = single-location condition.)

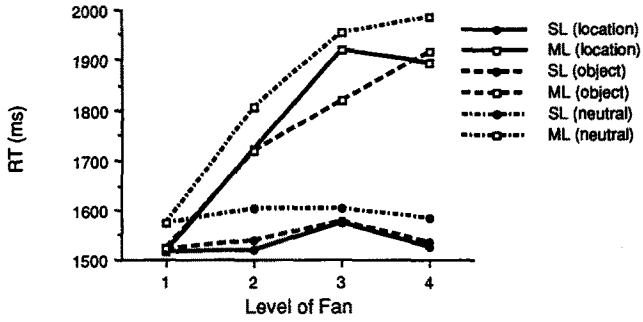

Figure 4. Comparison of the situation effect for location, object, and neutral instruction groups for Experiment 2. (RT = reaction time; SL = single-location condition; ML = multiple-location condition.)

was larger for the nonstudied decisions than for studied decisions. The other significant interaction was between location and fan, $F(2, 138) = 5.97$, $MS_e = 111730$. This indicates that the size of the fan effect was greater for the ML condition than for the SL condition, suggesting that a multiple-model search takes increasingly longer than a single-model search as fan increases. The fan effect was not significant for the SL condition, $F < 1$, but was significant for the ML condition, $F(2, 138) = 10.60$, $MS_e = 62751$. Additionally, Newman-Keuls tests on the ML data revealed that Fan Level 2 differed significantly from Fan Levels 3 and 4. There were no significant differences for the SL condition. The attainment of a significant Location × Fan interaction and the cleaner results of the Neuman-Keuls tests are attributed to the increased power as a result of more trials per cell and more subjects in this experiment compared with Experiment 1.

Instruction type. There were no significant effects involving the type of memorization instructions that the subjects received. Both the SL–ML difference and the Location × Fan interaction (i.e., the entire situation effect) were significant for each of the different instruction groups (all $ps < .05$; see Figure 4). Neuman-Keuls tests revealed differences similar to those reported for the combined conditions.

Errors. Subjects made an average of 2.5% errors on the decision trials. As in Experiment 1, there was a fan effect, $F(3, 207) = 3.29$, $MS_e = 7$. The percentage of errors increased with increasing fan: The means were 1.8%, 2.2%, 2.9%, and 3.0% for Fan Levels 1 to 4, respectively. There were more errors in the ML conditions (3.5%) than in the SL conditions (1.8%), $F(1, 69) = 15.21$, $MS_e = 40$. Additionally, the SL–ML difference interacted with studied–nonstudied probe decision, $F(1, 69) = 5.24$, $MS_e = 38$. There was a greater difference in error rate between the SL and ML conditions in the nonstudied probe decisions (1.4% to 4.1%) than in the studied decisions (2.3% to 3%). There was no significant effect of instruction type on error rate, although the location and object groups had fewer errors (2.2% for both) than the neutral group (3%). The error rates are consistent with the RT data. There is no evidence of a speed–accuracy trade-off.

Posttest questionnaire. Two subjects in the neutral instruction group were not asked the posttest questions as a result of experimenter error. Therefore, the following analyses

exclude these 2 subjects. We consider each of the questions in turn.

For the object question, the majority of subjects responded that they considered the object to be the same one in each of the locations it was associated with (60%). This pattern of responses was true for both the location (58.3%) and object (75%) groups, but not for the neutral instruction group (45.5%). However, chi-square tests did not reveal any significant differences across these groups. An ANOVA using the response to this question (same or different) as a between-subjects factor found no differences between the two groups for the recognition test RTs.

For the location question, 95% of the subjects said that they considered the location to be the same when multiple objects were 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 during the study portion of the experiment, only 1 location group subject reported not doing so, whereas 10 object group subjects 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 following or not following the memorization instructions were split into two groups, the SL–ML difference remained significant for both, $F(1, 13) = 33.30$, $MS_e = 86365$ and $F(1, 9) = 28.25$, $MS_e = 79647$, respectively. The size of the difference was 261 and 274 ms, respectively. This suggests that the subjects' opinion of their compliance with the instructions made no difference as to how the information was organized.

Discussion

This experiment suggests that, with the present materials, organization by location—or by situation occurring within a location—is powerful enough to override instructions to the contrary. 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 for memorization, so she grouped in terms of the location. Even though some object-group subjects did not follow instructions, those who reported using the instructed strategy still showed the situation 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 used. 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., only giving the "Where was the *object*?" questions to the object group) or presenting all the locations associated with an object together during study. However, the present experimental methods do seem to have had some impact on how subjects tried to organize the material. More subjects in the object group, compared with the other two groups, tended to consider the object to be the same instance when it was associated with multiple locations, although this disparity was not statistically significant. Despite this difference, the situation effect was not weakened in this group. It was apparently too difficult for the subjects to consider a group of facts about an object being in several locations as being consistent with a single situation.

Experiment 3

If our admittedly primitive account of how mental models are retrieved is accurate (see earlier discussion here), then it should be possible to reduce the amount of interference from competing mental models by selecting, by means of a cue, the single appropriate mental model before presentation of the memory probe. Also because the object and location concepts are treated differently in the way they are used to organize information, we expect different effects for each of these cue types. Thus, the cues used in the present experiment were the location concept from the probe sentence, the object concept, or a neutral cue. For example, if the probe sentence was "The ceiling fan is in the hotel," the location cue would be "hotel," the object cue would be "ceiling fan," and the neutral cue would be the word "ready." The neutral cue condition is expected to show the same pattern of results as in the previous experiments, and is used as a baseline to compare the object- and location-cue conditions.

For an object cue, not only will the appropriate mental model be selected, but so will all of the irrelevant mental models containing that object. These irrelevant mental models will continue to interfere with the selection of the appropriate one. Therefore, a significant SL–ML difference and Location × Fan interaction will remain. For the location-cue condition, however, the interference from the irrelevant mental models in the ML condition will be attenuated by the early selection of the appropriate mental model. Therefore, the SL–ML difference should be reduced or eliminated, and the Location × Fan interaction should be eliminated.

Another way of stating these predictions is in terms of the fan effects within each of the SL and ML conditions. For the SL conditions, no matter what the cue type, there will be no fan effect. The presentation of either an object or a location cue will not alter the pattern of retrieval times because there is only one mental model associated with both the object and location concepts. All the cue should do is speed overall retrieval time, but not alter its pattern.

For the ML condition, cuing with the object versus location concept of the probe sentence should produce different results. If the cue is the object concept, not only will the appropriate mental model be selected, but so will all of the irrelevant mental models containing that object, thus generating interference. So the fan effect will remain for the ML-object-cue condition, although overall RT will be speeded. If the cue is the location concept, however, a single mental model will be selected, thus reducing the amount of interference from the irrelevant mental models when the memory probe is presented, and resulting in a reduced or eliminated fan effect for the ML-location-cue condition in addition to reduced retrieval time.

In sum, there should be no change in the retrieval pattern for the neutral- and object-cue conditions. In the location-cue condition, however, there should be a reduced or eliminated situation effect as shown by a reduced or eliminated SL–ML

difference, an eliminated Location × Fan interaction, and a reduced fan effect for the ML condition.

Propositional network theory predicts a different pattern of results: The object- and location-cue types will speed retrieval to an equal degree in all conditions, but there will be no changes in the effect of fan level. Either type of cue would activate the appropriate node in the network and begin spreading activation, thereby facilitating retrieval. Because activation spreads bidirectionally and in parallel, it should make no difference which node is activated ahead of time. This point has been demonstrated by Anderson (1974).

The present study had three groups of subjects with 250, 500, and 1,000 ms cue–probe SOAs, respectively. The different SOA groups were used to more fully explore the effect of cue type, because the shorter SOAs may not allow sufficient time for cues to have their full impact on the retrieval process.

Method

Subjects. Seventy-two subjects, 24 in each SOA group, were tested. Additionally, each SOA group was divided into two sentence-type groups; OS and LS sentences. 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 vocabulary test.

Procedure. The procedure was largely identical to previous experiments except for the addition of the cue. During the recognition test, a location, an object, or a neutral (i.e., the word "ready") cue preceded each probe sentence by either 250, 500, or 1,000 ms. Subjects were instructed to use the cue to help them make the studied–nonstudied decision. There were four 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. The actual distance from the beginning of the cue to the initial letter of the subject noun in the probe sentence was four spaces or approximately 3 cm (the word "the" and a space). As in Experiment 1, both LS and OS sentences were used for different groups of subjects. As a result, for subjects receiving LS sentences, the location cue was near to its matching concept in the recognition sentences and the object cue was far from its matching concept. The opposite was true for the subjects receiving the OS sentences. The use of the two sentence types thus controlled for an effect of proximity of a cue to its matching concept in the probe sentence.

Results

Because of the cues, the RTs collected in this experiment were faster than in the previous studies, and the 500-ms lower end cutoff would have eliminated a substantial portion of the data. The lower end cutoff was consequently changed to 400 ms. The data are discussed by first presenting the studied–nonstudied, fan, and situation effect results as in the previous two experiments. Then the outcome of the predictions based on the different cue types are discussed, followed by the effects of sentence type and error analyses. The main effect and most of the interactions involving SOA were not significant ($Fs \leq 1.74$), with a major exception discussed later.

Studied–nonstudied probe differences and fan effect. The RT data were submitted to a 3 (SOA) × 2 (sentence type) × 2 (studied–nonstudied) × 4 (Fan Levels 1–4) × 3 (cue type) mixed ANOVA; the first two variables were between subjects. Studied probe decisions were faster than those for the nonstudied probes, $F(1, 66) = 189.02$, $MS_e = 61921$. There was a fan effect, $F(3, 198) = 9.67$, $MS_e = 121244$. There was also an interaction of fan with studied–nonstudied probe decisions, with a larger fan effect for nonstudied probe decisions compared with studied probes, $F(3, 198) = 4.98$, $MS_e = 56242$.

Situation effect. The RT data, summarized in Figure 5, were also submitted to a 3 (SOA) × 2 (sentence type) × 2 (studied–nonstudied) × 2 (SL–ML) × 3 (Fan Levels 2–4) mixed ANOVA. The SL–ML difference was significant, $F(1, 66) = 89.57$, $MS_e = 226197$, as was the Location × Fan interaction, $F(2, 132) = 7.60$, $MS_e = 161129$. The fan effect was significant only for the ML condition, $F(2, 132) = 9.75$, $MS_e = 33180$. Neuman-Keuls tests on the ML data revealed a significant rise in RT for each increase in fan level.

Effects of cue type. The pattern of RTs for each cue type for each SOA group can be seen in Figure 6. There was a main effect of cue type, $F(2, 132) = 220.12$, $MS_e = 50732$; object cues produced the fastest RTs ($M = 1{,}284$ ms), location cues the next fastest RTs ($M = 1{,}323$ ms), and neutral cues the slowest RTs ($M = 1{,}543$ ms). Neuman-Keuls tests showed that these conditions were all significantly different from one another. Additionally, cue type interacted with SOA, $F(4, 132) = 8.21$, $MS_e = 50733$. This was further qualified by an SOA × Cue Type × Location interaction, $F(4, 132) = 2.77$, $MS_e = 53581$. The triple interaction reflects a decreased SL–ML difference in the location-cue condition as SOA increases.

Neither the Cue Type × Location × Fan interaction nor the SOA × Cue Type × Location × Fan interaction was significant ($ps > .10$), but for two reasons a closer look at the SL and ML fans for each cue type is justified: First, there were two significant interactions involving cue type; second, specific predictions were made about the effects of the different cues on SL and ML fans. The relevant statistical results are summarized in Table 3.

The SL–ML difference and Location × Fan interaction were expected to remain significant in the neutral- and object-cue conditions, but be reduced or eliminated in the location-

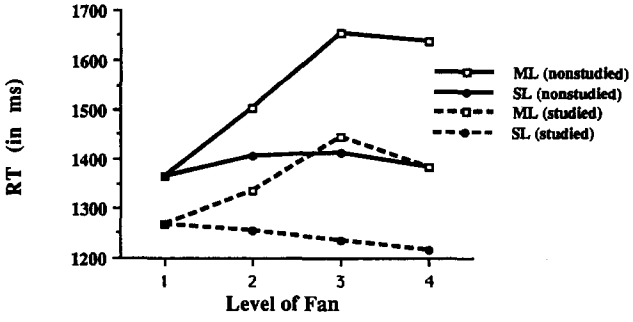

Figure 5. Situation effect for studied and nonstudied sentences for Experiment 3. (RT = reaction time; ML = multiple-location condition; SL = single-location condition.)

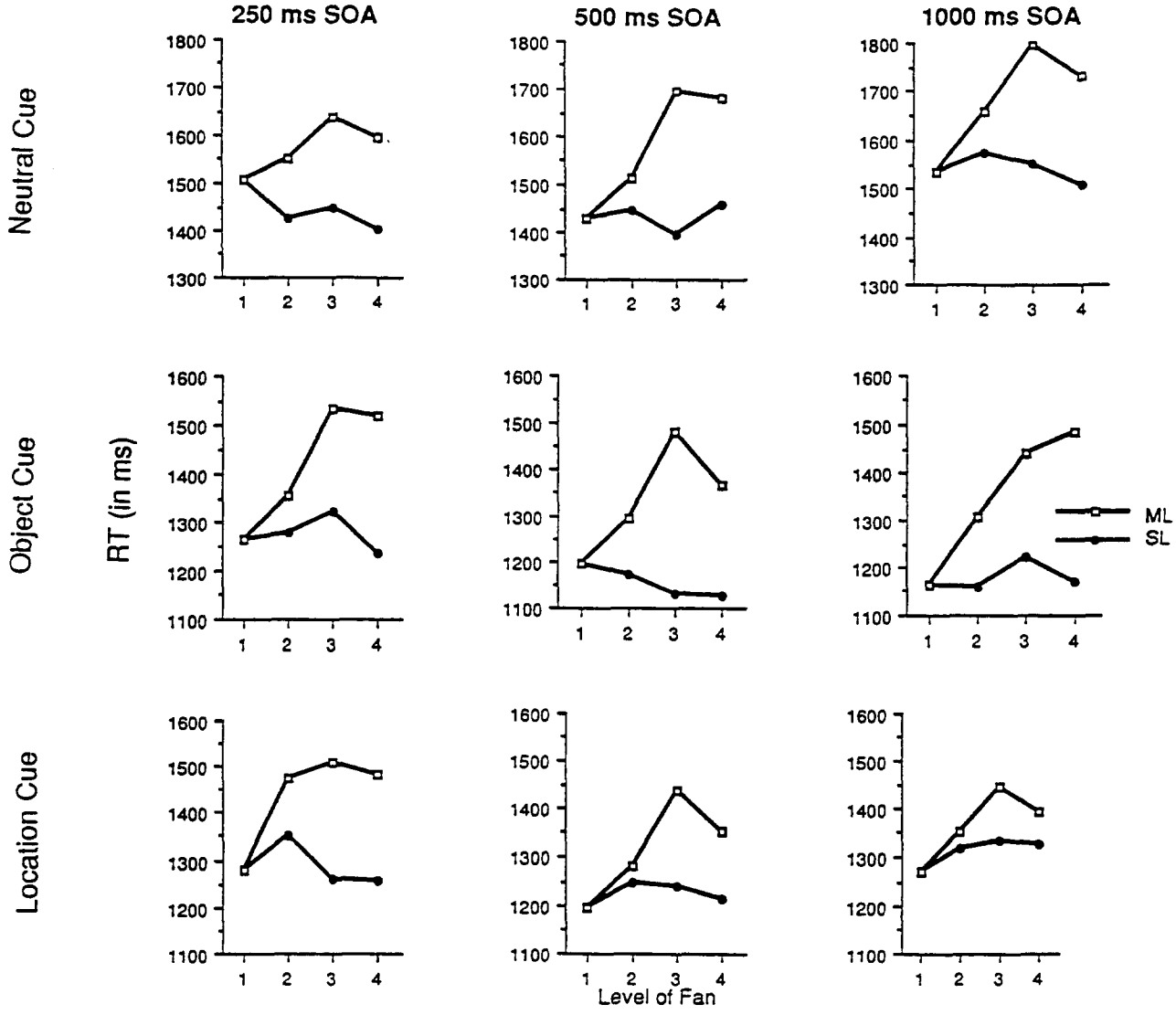

Figure 6. Comparison of the situation effect for neutral, object, and location cue conditions for the 250-, 500-, and 1,000-ms sentence onset asynchrony (SOA) groups. (RT = reaction time.)

cue conditions. These expectations were largely fulfilled. For all SOAs in the neutral-cue condition, as in previous experiments, SL RTs were faster than ML RTs, $F(1, 22) = 15.54$, $MS_e = 13258$, $F(1, 22) = 28.34$, $MS_e = 97888$, $F(1, 22) = 16.10$, $MS_e = 149916$, and $F(1, 66) = 56.97$, $MS_e = 126795$, for 250, 500, 1,000, and overall SOAs, respectively. The Location × Fan interaction was significant for the 500-ms SOA group and overall, $F(2, 44) = 4.84$, $MS_e = 69661$ and $F(2, 132) = 5.17$, $MS_e = 89293$, respectively.

In the object-cue condition, as expected, the situation effect was largely present. There was a significant SL–ML difference at each SOA, $F(1, 22) = 28.71$, $MS_e = 89677$, $F(1, 22) = 38.50$, $MS_e = 105790$, $F(1, 22) = 4.42$, $MS_e = 46871$, and $F(1, 66) = 111.17$, $MS_e = 92180$, for 250, 500, 1,000, and overall SOAs, respectively. Also the Location × Fan interaction was significant for the 250-ms SOA group, $F(2, 44) = 3.98$, $MS_e = 70468$, and overall, $F(2, 132) = 6.39$, $MS_e = 89300$, and marginally significant for the 500-ms SOA group, $F(2, 44) = 3.08$, $p < .06$, $MS_e = 101798$.

Finally, in the location-cue condition, the situation effect was present overall and for the shorter SOAs, but was absent at the longest (1,000 ms) SOA. The SL–ML difference was significant overall and for the 250- and 500-ms SOAs, $F(1, 22) = 54.46$, $MS_e = 13951$, $F(1, 22) = 8.12$, $MS_e = 131765$, and $F(1, 66) = 31.12$, $MS_e = 116922$, for 250, 500, and overall SOAs, respectively. However, it was not significant for the 1,000-ms SOA condition, $F(1, 22) = 2.15$, $MS_e = 167864$. The size of the SL–ML difference decreased with increased SOA in the location-cue condition, but did not for the other cue types. For the location-cue condition, the SL–ML differences were 188, 122, and 71 ms at the 250, 500, and 1,000 ms SOAs, respectively. The comparable SL–ML differences were 189, 238, and 227 ms for the object-cue condition and 169, 196, and 183 ms for the neutral-cue condition.

Table 3
Results for Predictions of Experiment 3

Effect	Predicted	SOA (ms) 250	500	1,000	Overall
SL–ML difference					
Object cue	+	+	+	+	+
Location cue	−	+	+	−	+
Neutral cue	+	+	+	+	+
Location × Fan interaction					
Object cue	+	+	*	−	+
Location cue	−	−	−	−	−
Neutral cue	+	−	+	−	+
Fan					
ML-object	+	+	+	+	+
ML-location	−	−	−	−	+
ML-neutral	+	−	+	−	+
SL-object	−	−	−	−	−
SL-location	−	−	−	−	−
SL-neutral	−	−	−	−	−

Note. SOA = sentence onset asynchrony; SL = single-location condition; ML = multiple-location condition; + indicates a significant ($p < .05$) result; * indicates a marginally significant ($p < .06$) result; and − indicates a statistically nonsignificant result.

Consistent with the predictions, and as already suggested by the overall analysis, the fan effect was not significant in any of the SL conditions. For the ML conditions, the predicted outcome varied with respect to cue type. The neutral- and object-cue conditions were expected to show fan effects, but the location-cue condition was expected to show reduced or eliminated fan effects. For the neutral cue, although the trends at each SOA are consistent with this expectation (see Figure 6), the main effect of fan was significant only in the 500-ms SOA group, $F(2, 46) = 5.94$, $MS_e = 40896$, and overall, $F(2, 132) = 6.50$, $MS_e = 53922$. By contrast, the ML-object-cue conditions completely confirmed expectations: In these conditions, there was a significant fan effect at each SOA, $F(2, 46) = 4.65$, $MS_e = 45487$, $F(2, 46) = 3.26$, $MS_e = 67096$, and $F(2, 46) = 4.42$, $MS_e = 46871$ for SOAs of 250, 500, and 1,000 ms, respectively, and $F(2, 132) = 10.65$, $MS_e = 51387$ overall. Although the data presented in Figure 6 are suggestive of fan effects in the ML-location-cue conditions, the statistical analyses indicate that, as expected, there was a reduced fan effect in these conditions. Specifically, the fan effect was significant overall, $F(2, 132) = 3.10$, $MS_e = 52451$, but it was not significant for any of the individual SOA groups.

The results of the cue-type analyses are less clear-cut than would have been desirable. Still, trends in the expected direction are readily detectable. Especially in the 1,000-ms SOA group, the results conform closely to the prediction of the mental model view. In particular, the SL–ML difference in location-cue condition was eliminated, whereas it remained in the other two cue-type conditions. Additionally, the ML condition fan effect was eliminated in the location-cue condition, but remained in the object cue condition. The only discordant note is the absence of a significant ML condition fan effect for the neutral-cue condition, but this seems to be an aberrant result given the repeated finding of ML-condition fan effects in Experiments 1 and 2.

Sentence type. As in Experiment 1, there was no main effect of sentence type ($F < 1$). However, there was an interaction with cue type, $F(2, 132) = 6.42$, $MS_e = 50732$. The OS sentence group had equal RTs for location and object cues (1,276 ms for both), but the LS sentence group had faster RTs with the object cue (1,293 ms) than with the location cue (1,371 ms). The reason for this difference is not readily apparent.

Errors. Subjects made an average of 3.1% ($SD = 1.9$) errors on the decision trials. There was no main effect of SOA. There was a marginally significant fan effect for errors, $F(3, 198) = 2.63$, $p < .06$, $MS_e = 30$, with 2.9%, 2.6%, 3.3%, and 3.6% errors for Fan Levels 1 to 4, respectively. There was also a significant interaction of fan effect with SOA, $F(6, 198) = 3.22$, $MS_e = 36$. Both the 250- and the 500-ms SOA groups showed significant standard fan-effect patterns, $F(3, 66) = 3.24$, $MS_e = 2941$, and $F(3, 66) = 2.94$, $MS_e = 1306$, for 250- and 500-ms SOA groups, respectively. However, the 1,000-ms SOA group pattern was erratic, with mean percentages of 3.6%, 2.7%, 3.6%, and 2.2% for Fan Levels 1 to 4, respectively. Additionally, there was an interaction of fan effect with studied–nonstudied probe decisions, $F(3, 198) = 3.31$, $MS_e = 8090$. There was a fan effect only for the nonstudied decisions, $F(3, 207) = 4.57$, $MS_e = 43$.

More errors were made in the ML condition than in the SL condition (a difference of 1.7%), $F(1, 66) = 22.16$, $MS_e = 83$. The SL–ML difference also interacted with studied–nonstudied probe decisions, $F(1, 66) = 6.50$, $MS_e = 58$. The SL–ML difference was greater for nonstudied decisions (2.5%) than for studied decisions (0.9%).

There was no main effect of sentence type. However, the Sentence Type × SOA × Cue Type interaction reached significance, $F(4, 132) = 3.13$, $MS_e = 3494$. The OS sentence groups had fewer errors except in the neutral-cue condition of the 250- and 1,000-ms SOA groups and in the location-cue condition of the 1,000-ms SOA group. The effect of cue type on error rate was not significant, with 2.8% errors for location cue, 3.5% for object cue, and 3.2% for the neutral cue. Overall, the error patterns parallel the RT patterns. There was no evidence of a speed–accuracy trade-off.

Discussion

The mental model view predicted that subjects' RTs would show a reduced or eliminated fan effect for the ML-location-cue condition as well as a reduced or eliminated SL–ML difference for the location-cue condition. Especially at the 1,000-ms SOA, these predictions were largely confirmed, and thus the results are supportive of the mental model view.

Admittedly, there were some failures to obtain predicted effects (e.g., the Location × Fan interaction was not always significant when predicted to be, but as noted, this may be due to a power problem). Also it appears that the cues had less of an effect on the RT pattern at the shorter SOAs than at the 1,000-ms SOA. Because mental models are rather large and complex cognitive structures, relative to simple propositions, it is understandable that a relatively long SOA is required to show a substantial effect of the sort investigated. As complex as these mental models may be, the ones generated

in the present study may not be complex enough to affect an internal search of the model, resulting in the absence of a fan effect for the SL condition.

General Discussion

Three experiments were conducted to assess whether the mental model view could predict aspects of performance in a fan effect paradigm. Subjects memorized lists of sentences that could be related in terms of either a location or an object. Subjects demonstrated an organization of information around the location concepts through faster RTs on a recognition test for conditions in which several objects were associated with a single location rather than the opposite. This situation effect supports a mental model theory in which information is represented in terms of the situation described. This effect remains even if syntactic form (Experiment 1) or instruction type (Experiment 2) is altered. Furthermore, retrieval is best facilitated by a cue if that cue selects the single mental model that contains the appropriate information (Experiment 3).

Subjects in these studies appear to have engaged in the comprehension of the texts (the facts) at a level much deeper than necessary and then used this more complex representation at retrieval. All that was required was that a surface structure or simple propositional representation of each fact be stored in and retrieved from long-term memory for successful performance. In fact, the latter is what should happen if the retrieval processes were relying on a propositional network. What seems to have occurred instead is 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. The data suggest that, even if other representational forms may have been generated, the mental model structures dominate performance. Consistent with the findings of Moeser (1979), the retrieval of information from these integrated representations did not produce a fan effect.

One possible factor that may have contributed to our results is a greater degree of overlearning of the SL sentences leading to a reduction in the fan effect. In fact, we found that, during the initial learning phase, there were fewer cued-recall errors for the SL sentences than for the ML sentences in Experiments 1 and 2, with 6.3 versus 8.2 errors, $F(1, 31) = 11.38$, $MS_e = 5.11$, and 7 versus 9 errors, $F(1, 69) = 15.86$, $MS_e = 8.83$, respectively, although there was no difference in Experiment 3 with 8 versus 7.6 errors ($F < 1$). It is unlikely that this learning advantage resulted in such a drastic reduction of the fan effect. Hayes-Roth (1977) found that it took 11 sessions of overlearning to reduce the fan effect!

A problem with the present data is that the suggested verification process might have been expected to produce a fan effect in the SL condition when in fact there was none. As a mental model becomes more complex with the addition of greater numbers of objects, it should take longer to search the model for a probed object. The reason for the lack of such a finding is currently unknown. Our best guess is that a fan effect would be revealed if fan sizes were increased so as to be large enough to tax short-term memory capacity (i.e., greater than six or seven).

Previous Fan Effect Studies

We next turn to the issue of the generalizability of the mental model view. At the current stage of development, a definitive conclusion on its ability to explain previous fan-effect experiments is premature. However, an outline of such an explanation can be offered. We begin with findings that might seem contradictory to those reported here. The first fan effects studies were reported by Anderson (1974). In these experiments, subjects were presented sentences about people being in locations. In contrast to the present results, Anderson found equal fan effects from both the person and location concepts. That is, there was no evidence of the organization of information by either the location or person concept that would suggest the use of a mental model. We (Radvansky, Zacks, & Irwin, 1990) also conducted similar experiments using person–location (instead of object–location) sentences and found fan effects for both SL and ML conditions.

Why would the use of persons rather than inanimate objects for the nonlocation concepts make a difference? Perhaps it is because it is possible to think of a person as traveling from place to place in a situation composed of a course of events. That is, subjects could form person-based mental models incorporating multiple locations. As such, both the location and person concepts might compete for status as the concept by which the mental model is organized. If this were true, then the situation effect could be obscured, with a person organization being chosen part of the time and a location organization the rest of the time. In one test of this idea, we used person–location sentences in which the location was a place that typically contains a single person (e.g., a phone booth). The idea here was that, because the situation of many people being in a phone booth is unlikely, subjects would be influenced not to use location-based mental models but instead to encode the facts in terms of situations in which each person travels from place to place. What was found in that study was a clear situation effect suggesting organization of the facts around the person concept. If, as this line of reasoning suggests, the subjects in Anderson's (1974) research used a mixture of person-based and location-based situation representations, the mental model view could be used to account for his data.

The present study is not the only evidence for reduced fan effects. There have been numerous studies showing that the fan effect can be attenuated when the facts associated with a concept are thematically related (e.g., Jones & Anderson, 1987; McCloskey & Bigler, 1980; Myers, O'Brien, Balota, & Toyofuku, 1984; Reder & Anderson, 1980; Smith, Adams, & Schorr, 1978). A study by Jones and Anderson (1987) is typical. Fan levels of 1, 3, and 6, were used. For half of the person–words, their associated predicates were unrelated to one another (e.g., research, police, and forest), and for the other half they were related (e.g., rifle, hunter, forest). Related material consistently produced shorter RTs than unrelated material (although this difference was only significant in

Experiment 2). Additionally, visual inspection (neither the Fan × Relatedness interaction nor the fan effects for the two relatedness conditions were reported) of the graphs (Jones & Anderson, 1987, pp. 143, 146) suggests that the unrelated sets produced increased RTs with increasing fan, whereas the related sets produced RT patterns that were comparatively flat.

Explanations of such findings have been given in terms of thematic subnodes (e.g., Reder & Anderson, 1980) in which a node of the network serves to organize the related information, thus reducing the division of activation. It has also been proposed that subjects sometimes use a relatedness judgment strategy (e.g., Jones & Anderson, 1987), which is facilitated by a large number of preexperimental associates among the probed concept nodes.

Although these explanations may be adequate for the materials of previous studies, they cannot be extended to the materials of the present article. The objects associated with a single location were not preexperimentally associated with each other or the locations. By contrast, a mental model level of explanation can account for both sets of findings. For example, in the Jones and Anderson (1987) materials, the related predicates can be 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 result is the situation effect described previously here.

The Myers et al. (1984) research provides an especially interesting test of the mental model view. Subjects were given lists of sentences that included fan sizes of 3 and 6. Each of the sentences was about a person engaged in some sort of activity, and all of the activities were associated with particular themes (e.g., going to a baseball game). For a given set, the sentences could have either low or high thematic relatedness (Myers et al. referred to this as low and high integration). A high degree of relatedness was accomplished by making the sentences causally linked. It was found that, whereas low-relatedness sets showed a small fan effect, high-relatedness sets showed no fan effect or even a reversed fan effect (i.e., shorter RTs with increased level of fan).

Myers et al. (1984) used an elaboration of ACT to account for their results, including the reversed fan effect. Here we suggest how these data can also be accounted for by considering a mental model view. Our explanation assumes that subjects were building mental models organized around the person (e.g., the situation of the banker going to see a ballgame). This is a reasonable notion to consider because all of the facts about one person were presented at once, and we know from other experiments we have conducted (prior discussion) that person concepts can be used to organize mental models. Because of the causal linkages present in the high-relatedness, but not low-relatedness, condition, it is likely that the set of facts associated with a particular person was more consistent with a single situation in the high-relatedness condition than in the low-relatedness condition. Therefore, the subjects were more likely to create a single mental model for a set of facts in the high-relatedness condition. Consequently, one would expect faster RTs in the high- than in the low-relatedness condition. The reason that the Fan Level 6 condition produced a smaller or even negative fan effect for the highly related sets was that the Fan Level 3 condition did not include the material that differentiated the high-relatedness condition from the low-relatedness condition. In fact, the Fan Level 3 condition was the same for both conditions. So it is conceivable that the subjects may have been less likely to integrate all of the facts into a single mental model for the Fan Level 3 than for the high-relatedness Fan Level 6 condition, and that any competing and irrelevant mental models may have interfered with the retrieval, thus potentially resulting in slower RTs than for the Fan Level 6 high-relatedness condition.

Why Mental Models?

From this brief overview, it can be seen that it may be possible to develop mental model explanations of the results of previous fan effect experiments. In addition, by considering mental models we gain a perspective of how information might be organized in memory that is not available within the propositional network viewpoint. For example, the questions asked in the present article as well as their predicted experimental results were derived directly and readily from a mental model view. The situation effect itself is based on the notion that the mental representations people construct are organized in terms of real-world situations. It could be argued about Sentences 1 to 3 that these three sentences are all thematically related (they are all about a cola machine being places). However, our data have shown that subjects did not seem to consider this as a way to organize the information. Instead, subjects strongly preferred to organize the facts by location presumably because a location organization is consistent with a single situation.

Although the propositional network view indicates how information can be organized and integrated in a network, it does not provide a guide as to how the organization of situational information should be accomplished in the absence of or in competition with preexperimental, thematic, or causal linkages. A propositional network account for the present data could perhaps be constructed by adding new productions to current theories that would guide network construction so that subnetworks of token nodes would be consistent with a single situation. However, such changes to the propositional network view would be ad hoc and, in the case suggested, would include the mental model view through the "back door."

In response to the argument (Rips, 1986) 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, we offer the present studies as evidence that mental models can provide cognitive psychology with a predictive paradigm. Specifically, it is possible to predict various characteristics of the mental model representation and effects of these characteristics on cognitive processes.

References

Anderson, J. R. (1974). Retrieval of propositional information from long-term memory. *Cognitive Psychology, 6,* 451–474.

Anderson, J. R. (1976). *Language, memory, and thought.* Hillsdale, NJ: Erlbaum.

Anderson, J. R. (1983). *The architecture of cognition.* Cambridge, MA: Harvard University Press.

Bransford, J. D., & Franks, J. J. (1971). The abstraction of linguistic ideas. *Cognitive Psychology, 2,* 331–350.

Glenberg, A. M., Meyer, M., & Lindem, K. (1987). Mental models contribute to foregrounding during text comprehension. *Journal of Memory and Language, 26,* 69–83.

Hayes-Roth, B. (1977). Evolution of cognitive structures and processes. *Psychological Review, 84,* 260–278.

Johnson-Laird, P. N. (1983). *Mental models: Towards a cognitive science of language, inference, and consciousness.* Cambridge, MA: Harvard University Press.

Jones, W. P., & Anderson, J. R. (1987). Short- and long-term memory retrieval: A comparison of the effects of information load and relatedness. *Journal of Experimental Psychology: General, 116,* 137–153.

McCloskey, M., & Bigler, K. (1980). Focused memory search in fact retrieval. *Memory & Cognition, 8,* 253–264.

Moeser, S. D. (1979). The role of experimental design in investigations of the fan effect. *Journal of Experimental Psychology: Human Learning and Memory, 5,* 125–134.

Myers, J. L., O'Brien, E. J., Balota, D. A., & Toyofuku, M. L. (1984). Memory search without interference: The role of integration. *Cognitive Psychology, 16,* 217–242.

Radvansky, G. A., Zacks, R. T., & Irwin, D. E. (1990). *Mental models and small places.* Poster presented at the second annual meeting of the American Psychological Society, Dallas, TX.

Reder, L. M., & Anderson, J. R. (1980). A partial resolution of the paradox of interference: The role of integrating knowledge. *Cognitive Psychology, 12,* 447–472.

Rips, L. J. (1986). Mental muddles. In M. Brand & R. M. Harnish (Eds.), *The representation of knowledge and belief* (pp. 258–286). Tucson, AZ: University of Arizona Press.

Smith, E. E., Adams, N., & Schorr, D. (1978). Fact retrieval and the paradox of interference. *Cognitive Psychology, 10,* 438–464.

Received November 9, 1990
Revision received February 6, 1991
Accepted February 12, 1991 ■