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Retrieval From Temporally Organized Situation Models

Gabriel A. Radvansky
University of Notre Dame

Rolf A. Zwaan
Florida State University

Todd Federico and Nancy Franklin
State University of New York at Stony Brook

Time is an important part of establishing situations in the world. As such, temporal information should be reflected in the organization of information into situation models. This article reports 3 experiments that explore whether people will integrate sets of related facts into situation models in a time-based fashion. People memorized lists of facts and then took a speeded recognition test. A retrieval interference methodology was used to assess whether they had integrated the facts into situation models. The presence of interference indicated a lack of integration. In contrast, a marked reduction or an absence in interference indicated integration. In 2 experiments, time-based integration was observed when common time periods were referred to by either events (e.g., "when the camera flashed") or verb tense (i.e., past, present, and future). A 3rd experiment demonstrated that common time periods alone are not sufficient; the information must be allowed to occur potentially within the same situation.

A situation can be characterized as a spatial–temporal framework in which a set of entities stand in relation to each other (Barwise & Perry, 1983; Johnson-Laird, 1983; Radvansky & Zacks, 1997; Zwaan & Radvansky, 1998). Situations are often described through language, and people typically combine this information with their prior knowledge to create situation models[1] (Johnson-Laird, 1983, 1989; van Dijk & Kintsch, 1983). Thus, a *situation model* is a representation of the situation described by a text, rather than a representation of the text itself (cf. Glenberg, Meyer, & Lindem, 1987). The purpose of the present series of experiments was to assess whether people can integrate a set of facts into situation models on the basis of temporal information.

The Role of Time in Situation Models

In theories of situation models, it is assumed that people represent events that occur in a common spatial–temporal framework. According to some theories of situation models, such as the event indexing model (Zwaan, Langston, & Graesser, 1995; Zwaan, Magliano, & Graesser, 1995), temporal information, along with location information, is an important dimension that people use to interpret situations. When a person moves out of a specified location, or enough time has elapsed, a new situation is present, and a reader should create a new situation model to represent that situation (see also Anderson, Garrod, & Sanford, 1983). The vast majority of work on situation models has either studied spatial relations in situation models or has used spatial relations to study other aspects of how situation models are structured or operate. There has been comparatively less work on temporal relations. This is somewhat surprising if one considers the special role that time has in language. Every sentence obligatorily contains information on the absolute or relative time at which the event described in the sentence occurred (Miller & Johnson-Laird, 1976; Quine, 1960). For example, every grammatical sentence in English and many other languages contains a verb. Verbs have tense morphemes attached to them that indicate whether they occurred before (past tense), after (future tense), or concurrently with (present tense) the moment of an utterance. Other situational dimensions that are commonly studied in the memory and text comprehension literature, such as space and causation, do not have such an obligatory linguistic status. Furthermore, temporal information can be conveyed in every major word class (Miller & Johnson-Laird, 1976). The fact that temporal information is obligatory and so richly encoded in grammar and the lexicon suggests that it may play an important and complex role in segregating and conveying situational information.

Gabriel A. Radvansky, Department of Psychology, University of Notre Dame; Rolf A. Zwaan, Department of Psychology, Florida State University; Todd Federico and Nancy Franklin, Department of Psychology, State University of New York at Stony Brook.

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Correspondence concerning this article should be addressed to G. A. Radvansky, Department of Psychology, University of Notre Dame, Notre Dame, Indiana 46556. Electronic mail may be sent to Gabriel.A.Radvansky.1@nd.edu.

[1] Previous research has used both the terms *situation model* and *mental model* to refer to this type of representation. *Situation model* is used here because it more accurately reflects the type of representation that is investigated here (i.e., a mental representation of situation-specific information).

The majority of work on how temporal information is involved in situation models has focused on the issue of how shifts in time can lead a person to either update a current model or shift to a new model altogether. When a small shift in time has occurred, such as "a moment later," people do not seem to create a new situation model. They seem to treat the situation as being functionally the same. However, when there has been a relatively large time shift, such as "a day later," a new situation model may be created (Zwaan, 1996; see also Carreiras, Carriedo, Alonso, & Fernandez, 1997). So time is an important dimension along which situation models are structured.

There are several ways in which language conveys information about the temporal relations between events. First, event times can be mapped onto an absolute time scale by temporal adverbials, as in "On May 15, 1989, I broke my ankle." Second, events can be related to other events, as in "It began to rain when the game started" by the use of time adverbials. Third, event times can be related to the moment of utterance via tense morphemes (see Reichenbach, 1947, for a seminal study). Consider sentences 1a–c.

(1) a. I see your brother.
b. I saw your brother.
c. I will see your brother.

In 1a, the event is concurrent with the moment of utterance, whereas the event occurred before the moment of utterance in 1b and will (in all likelihood) occur after it in 1c. In this article, we investigated whether readers make use of the latter two types of cues, relative temporal markers and tense, to construct time-based situation models. Descriptions of this sort constitute large time shifts from the perspective of the strong iconicity assumption (Zwaan, 1996). Consequently, it would be expected that people would be unwilling to treat the items in this set as being part of a single situation. Instead, it is clear that different time frames are involved, and so these statements describe different situations.

According to the view that we are putting forward here, people create situation models of the situations described in each of a set of study sentences. One plausible way in which this could occur, although not critical for the rest of the article, is that as each sentence is encountered, a person will first check to see whether it is consistent with the currently active situation model. If so, then the information will be integrated with it (although there are some circumstances in which readers may not notice inconsistencies; see, e.g., O'Brien & Albrecht, 1992). Presumably this is what typically occurs during language comprehension, although it is less likely to occur in the current experiments in which the information is presented in a more random order. If immediate integration is not possible, then the person may retrieve information from previously created situation models that are stored in long-term memory. It may be that a person will retrieve a previously created model and can integrate the new information with it. If the information is neither consistent with the current model nor with any models stored in long-term memory, then the person will construct a new situation model for that information.

In the text comprehension literature, situation models typically are defined in terms of their content rather than their representational format. That is, situation-model theorists argue that situation models are an amalgamation of linguistic input information and activated world knowledge and expectations, but they tend to be agnostic with regard to whether situation models are propositional representations or other types of representations, such as mental images (e.g., van Dijk & Kintsch, 1983). This is also the view taken in studies on the role of temporal information in situation-model construction during narrative comprehension (e.g., Carreiras et al., 1997; Zwaan, 1996).

The focus of the current experiments is not on the construction process per se but on how the organizational characteristics of time can affect information integration or segregation into situation models and the later retrieval of models that would be created in this way. In the context of the present experiments, it is argued that time is an important dimension that a person can use to integrate information into situation models. When a common time frame is indicated or implied, this may allow a person to integrate information. However, if different time frames are indicated or implied, this would block the integration of the information, leading to the creation of separate models.

Several studies have investigated how people use temporal markers to form situation models, using comprehension (Anderson et al., 1983; Carreiras et al., 1997; Mandler, 1986; Zwaan, 1996) and reasoning (Schaeken, Johnson-Laird, & d'Ydewalle, 1996) paradigms. Such experiments generally have studied linguistic cues that encourage readers to maintain an existing situation model (e.g., with phrases like "a moment later") or to close the current model and create a new one (e.g., with phrases like "the next day"). In contrast, in the current article we focus on the use of temporal markers, such as events and verb tense, that cue people to integrate separate pieces of information into a single situation model. We will assess this with a memory retrieval paradigm.

Assessment of Situation Model Integration

Memory retrieval is affected by the number of situation models that compose a search set. In particular, retrieval is influenced by whether a set of facts that are related by virtue of having overlapping concepts refers to a single situation, and thus a single model, or to multiple situations, and thus several models. In a series of experiments (Radvansky, 1998; Radvansky & Zacks, 1991; Radvansky, Spieler, & Zacks, 1993; Radvansky, Wyer, Curiel, & Lutz, 1997; Radvansky, Zacks, & Hasher, 1996), the fan effect paradigm has been used to assess the impact of situation models on memory retrieval. A *fan effect* is an increase in retrieval time with an increase in the number of associations to a concept in a memory probe (Anderson, 1974). For example, it takes less time to retrieve the fact "The yuppie is in the park" if that is all that is known about the yuppie than if a person also knows that "The yuppie is in the bank" and "The yuppie is in the BMW dealership."

The idea used here is that a fan effect will be observed in cases for which several related facts refer to several situations and are likely to be stored in several situation models. During memory retrieval, all of those models containing the concepts expressed in the memory probe will be activated. Provided that a person is engaged in more than just a plausibility assessment (e.g., Reder & Ross, 1983), one model must be selected to be brought into working memory to have its contents examined. The activation of multiple situation models produces competition and retrieval interference, leading to a fan effect. The more irrelevant situation models that are activated because they contain concepts present in the memory probe, the longer the response time.

In contrast, a fan effect is not observed, or at least is greatly attenuated, when two or more related facts refer to a single situation and can therefore be stored in a single situation model. During memory retrieval, there are no additional competing representations to produce interference. As a consequence, response time is unchanged and little or no fan effect is observed. (This argument assumes that the models themselves are relatively simple; otherwise, the complexity of the structure of the model may have an impact on response time.)

As an example, in a basic experiment studying spatial relations (e.g., Radvansky et al., 1993), people memorized a list of 18 sentences about objects in locations, such as "The potted palm is in the hotel." These sentences were studied one at a time and in a random order, so that any organization was imposed by the participant. Across the entire list, each object and location had one to three associations. These sentences could be divided up into three conditions. Sentences in which an object is in several locations but each location has only a single object represented the *multiple-location* condition. Those sentences in which an object is in only one location and the location contains many objects represented the single-location condition. The rest of the sentences with several associations for both the object and location concepts provided the appropriate number of associations in the single- and multiple-location conditions and otherwise served as *fillers*.

Let us consider the multiple-location and single-location conditions in more detail. In the multiple-location condition, a single object is described as being in several locations. For example, a "potted palm" may be in a "hotel," a "cocktail lounge," and a "high school." As a result, a separate situation model is created that corresponds to each of the different locations the object is in. During retrieval, when a person is required to verify a multiple-location fact, not only is the appropriate situation model activated but so are the other models that also contain the concepts in the memory probe. For example, in verifying the fact "The potted palm is in the hotel," not only is the hotel model activated but so are the cocktail lounge and high school models, although to a lesser degree. These related but irrelevant situation models interfere with a person's ability to retrieve the desired representation. Recent research suggests that these related but irrelevant models are actively suppressed (Radvansky, 1998). As a result, there is an increase in retrieval time accompanying an increase in the number of these distracting models, and hence a fan effect.

Now consider the single-location condition in which several objects are in a single location. For example, in the "city hall" there may be an "oak counter," a "revolving door," and a "waste basket." Unlike the multiple-location condition, these facts are all consistent with a single situation in the world, and so only a single model needs to be created. During retrieval, only the one model is activated; there are no related distractor models that need to be inhibited. As a result, response time is relatively constant as the number of objects associated with the location increases.

The Present Experiments

We sought to determine whether time-based situation model organizations could be observed using a similar methodology. Our interest was in examining the effects of different temporal markers and their interaction with world knowledge on situation model organization. The basic idea was that if people are able to integrate a set of overlapping facts into a common time-based situation model, then the retrieval interference effect would be attenuated or eliminated. A condition that would conform to this case would be one in which there are sentences that refer to a set of events that all occur within the same time period. This is referred to as a *same-time* condition. In contrast, when a set of overlapping facts are not integrated into a single time-based situation model, then retrieval interference would be observed. A condition that would conform to this case would be one in which there are sentences that refer to something that occurs in several time periods. This is referred to as a *different-times* condition. Therefore, evidence for time-based situation models would be a significant Condition × Fan interaction in which there is a clear fan effect in a different-times condition and a substantially attenuated or absent fan effect in a same-time condition.

Experiment 1

The goal of Experiment 1 was to find evidence for the use of time-based situation models. This experiment used the retrieval paradigm developed by Radvansky and Zacks (1991). An effort was made to ensure that both clear time periods and spatial locations were involved so that they could be used for the frameworks of the situation models. People memorized a list of sentences of the form "The [person] was [activity] when the [event]," such as "The banker was unbuttoning his vest when the camera flashed." People were told that all of the study sentences referred to events that occurred at a party, which provided a common spatial location that each of the situation models could be constructed around.

The times were identified by punctual events to distinguish each time period uniquely without resorting to predefined temporal structures (such as "at 8:45"), which we thought could bias the results. Specifically, we were concerned that under such circumstances the data would be more revealing of preexperimentally learned temporal structures rather than the situation models in which we were interested. The events were all ones that could plausibly occur during a party, such as a camera flashing or a phone ringing. Activities were placed in each of the time periods, such as stirring coffee or fixing a tie. Because activities do not happen by themselves, they were described as performed by different people. That is, people were used in the sentences, but because each person was used only once, no organization based on the person was possible.

The prediction of the situation model view is that if people integrate a set of facts into situation models based on a common time period, then there should be a greater fan effect for the different times condition than for the same time condition. This is because it is plausible for several activities to be happening at one time. For example, the banker could be unbuttoning his vest, the lawyer could be stirring his coffee, and the farmer could be checking his watch, all when the camera flashed.

Method

Participants. Forty-eight people were recruited from the subject pools at Florida State University, the State University of New York at Stony Brook, and the University of Notre Dame and were given partial class credit for their participation. One participant was replaced for having errors of more than 10% on the recognition test, and 6 for failing to complete the experiment.

Materials and procedure. Following Radvansky et al. (1993; Radvansky, 1998; Radvansky et al., 1996, 1997), participants memorized a list of 18 sentences through a study-test procedure. For Experiment 1, study sentences were of the form "The [person] was [activity] when the [event]," such as "The architect was fixing his tie when the curtain tore." In previous research (Radvansky, 1998; Radvansky & Zacks, 1991; Radvansky et al., 1996) the order of the concepts in the study sentences was found to have no impact on the resulting pattern of data from the recognition test. Because of this, and because we have no theoretical reason to expect this would have an effect, we did not vary concept order. Thus, this factor was not manipulated in these experiments. The person concepts were all occupation titles drawn from the Battig and Montague (1969) category norms, with the restriction that no two titles began with the same letter. A different person concept was used in each study sentence to avoid the possibility of putting a person-based organization in competition with a time-based organization. The activities were all ones that could occur at a party and are typically confined to a single person. Finally, the events were all ones that (a) could occur at a party, (b) could be used to identify punctual time periods, (c) are typically not causally or thematically related to one another or to the activities used, and (d) are likely to be perceptible by most people at the party.

Activities and events were combined to form study sentences in a fashion similar to earlier studies. This combination of activities and events resulted in conditions in which there were one to three associations for both activities and events. An example of the combination of associations composing a study list for a hypothetical participant, as well as a sample study list with the critical items marked, is presented in Figure 1. For four of the sentences, there was only one association for both the activities and events (e.g., "The architect was fixing his tie when the curtain tore"). Two of these Fan Level 1 sentences were arbitrarily assigned to the same-time condition, whereas the other two Fan Level 1 sentences were assigned to the different-times condition. These sentences served as a baseline with which to compare higher fan levels. In addition, there were two sentences in each of the remaining

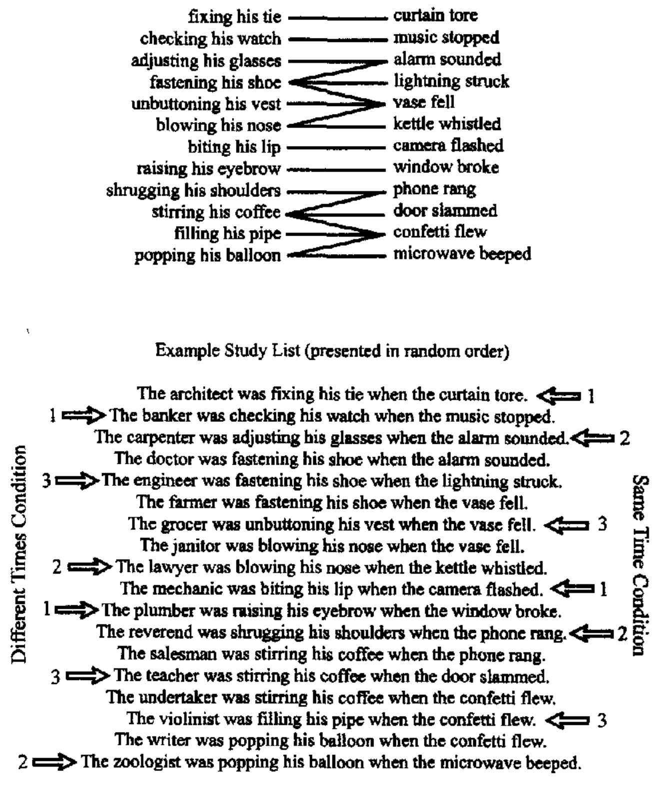

Figure 1. The structure of the study list concept associations of a hypothetical participant in Experiment 1. Those sentences contributing to the same-time and different-times conditions are marked on the sample study list along with the corresponding level of fan.

activity–event combinations. Along with the designated Fan Level 1 items, those sentences in which a single activity was associated with several events composed the different-times condition, whereas those sentences in which several activities were associated with a single event composed the same time condition. A different random assignment of activities and events to each condition was used for each person.

During memorization, each person was presented with the study list and instructed to memorize the sentences as efficiently as possible. The sentences were displayed one at a time in white on a black background for 7 s each on a PC-compatible computer running in 40-column presentation mode. The sentences appeared halfway down the screen, beginning on the left-hand edge. A different random presentation order was used on each cycle. After the list had been presented, a set of test questions was given. For Experiment 1, the test questions were of the form "When was the [person] [activity]?" and "What was the [person] doing when the [event]?" for each event and activity, respectively. The test questions were randomly ordered on each cycle. For those activities done by more than one person (at different times) and for those events involving multiple people (doing different activities), all of the people were mentioned in the questions, such as "When were the architect, banker, and carpenter fixing their ties?" or "What were the architect, banker, and carpenter doing when the curtain tore?" The participants typed their answers into the computer. The computer then checked the answer and indicated whether it was correct or not. If the answer or answers were incorrect or incomplete, feedback was provided. These responses were recorded to a file. After answering all of the test questions, the participants returned to the study portion. The criterion for memorization was the ability to answer correctly all of the test questions twice in a row.

After memorization, a speeded recognition test was given. In this test, sentences were presented one at a time. The task was to indicate whether the sentence was studied or not. Each sentence was presented 12 times, and the order of probe presentation in the recognition test was randomized within each block. Half of the probes were studied and half were not. Participants were allowed a self-timed break at the end of each quarter of the recognition test. The recognition test was timed and administered on the computer. People pressed the left button on a computer mouse to indicate a studied fact and the right button to indicate a nonstudied fact, people were encouraged to respond as quickly and as accurately as possible.

Nonstudied probes were generated through recombinations of activities and events from within the same cell of the design. The person concepts were yoked to the activities. Therefore, a person was never described as performing an incorrect activity. This was done to focus participants' attention on the activity and event concepts, and not on the person concepts. For example, if the studied sentences from the same cell were Sentences 2 and 3, the nonstudied sentences would be Sentences 4 and 5. Because the same number of associations are involved for the activity and event concepts for the nonstudied sentences, they can be assigned to same-time and different-times conditions and can be analyzed as such.

2. The architect was fixing his tie when the curtain tore.
3. The banker was checking his watch when the music stopped.
4. The architect was fixing his tie when the music stopped.
5. The banker was checking his watch when the curtain tore.

There are three other possible ways the nonstudied probes could be generated. The first possibility would be to recombine the person and activity concepts and yoke the activities and events together. We elected not to do so because this would have directed participants' attention to the associations between the person and activity concepts when what we were theoretically interested in was the association between the activities and events. The second possibility would be to yoke the person and event concepts together. The third possibility would require two or more kinds of recombinations. These latter two alternatives were not chosen because although the critical association between the activities and events is needed for verification, people would again have to allocate attention to the association between the person and the activity, which would introduce uninformative noise into the response times. Yoking the person with the activity allows the memory search to be more focused on the activity–event relation (e.g., Singer, Parbery, & Jakobson, 1988). Because our concern is with how people are treating the associations between the activities and events, our choice seemed the best one.

If a person responded incorrectly, immediate feedback was given consisting of a line that read either "*ERROR* SENTENCE STUDIED" or "*ERROR* SENTENCE NOT STUDIED," whichever was appropriate. This feedback was presented for 1 s. A set of 18 practice trials was provided to familiarize the participants with using the mouse buttons. On the practice trials the computer either displayed "SENTENCE STUDIED" or "SENTENCE NOT STUDIED," and the participant pressed the appropriate button.

Only the data from probe sentences for which there was one association with one concept and one to three associations with the other were analyzed. Those sentences from cells in which several activities were associated with several events, although presented, were not entered into the analysis. They were omitted because they do not address the question asked in this experiment: Are there fan effects in the same-time and different-times conditions?

For the analysis, trials for which the response times were shorter than 500 ms or longer than 10 s were eliminated from the analysis as anticipations and lapses of attention, respectively. In addition, responses that were greater than 2.5 standard deviations from a person's mean in a given cell of the design were eliminated as outliers. None of the data eliminated from the analyses were counted as errors. This trimming procedure dropped 4.1% of the data from the analyses for Experiment 1. Item analyses were not done because each person received a different set of materials (see also Singer et al., 1988).[2]

Results

Learning. Participants took an average of 6.6 ($SD = 2.17$) cycles to memorize the study sentences. The learning data also were analyzed with respect to the different conditions particular items were in. For each question, the point during learning at which each particular concept pair was correctly recalled for both the types of questions (i.e., asking for the activity or event) was identified. These data were then submitted to a 2 (Condition) × 2 (Fan) analysis of variance (ANOVA). For all analyses, unless otherwise mentioned, a rejection criterion of $p < .05$ was assumed. The results revealed a significant main effect of fan, $F(2, 94) = 10.83$, $MSE = 1.10$, with a greater number of trials needed with greater associative complexity (Fan Level 1 = 2.6; Level 2 = 3.0; Level 3 = 3.3 trials). No other effects were significant. There were no other significant effects, $Fs < 1$.

Response times. The response time data are summarized in Figure 2.[3] These data were submitted to a 2 (studied–nonstudied) × 2 (condition: same time/different times) × 3 (fan) repeated measures ANOVA. There were significant main effects of condition, $F(1, 47) = 4.95$, $MSE = 200{,}433$, and fan, $F(2, 94) = 6.91$, $MSE = 176{,}782$, and, importantly, a significant Condition × Fan interaction, $F(2, 94) = 3.06$, $MSE = 149{,}794$, $p = .05$. Simple effects tests showed that the fan effect was significant for the different-times condition, $F(2, 94) = 8.04$, $MSE = 193{,}891$, but not for the same-time condition, $F < 1$. This is consistent with the idea that people created time-based situation models with these materials.

In addition to these effects, there was also a significant main effect of studied–nonstudied, $F(1, 47) = 4.31$, $MSE = 69{,}813$, with people responding faster to studied probes (2,132 ms) than to nonstudied probes (2,178 ms).

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[2] All of the analyses reported in this article were collapsed across data collection site because this factor did not interact with anything else.

[3] The data from the cells in Experiment 1 for which there were multiple associations with both the activity and the event were considered fillers, and so were not analyzed. Using the notation *X-Y*, in which *X* refers to the activity fan, and *Y* refers to the event fan, the mean response times for the studied probes were 2,410, 2,362, and 2,485 ms for the 2-3, 3-2, and 3-3 cells, respectively, and for the nonstudied probes were 2417, 2407, and 2545 ms, respectively.

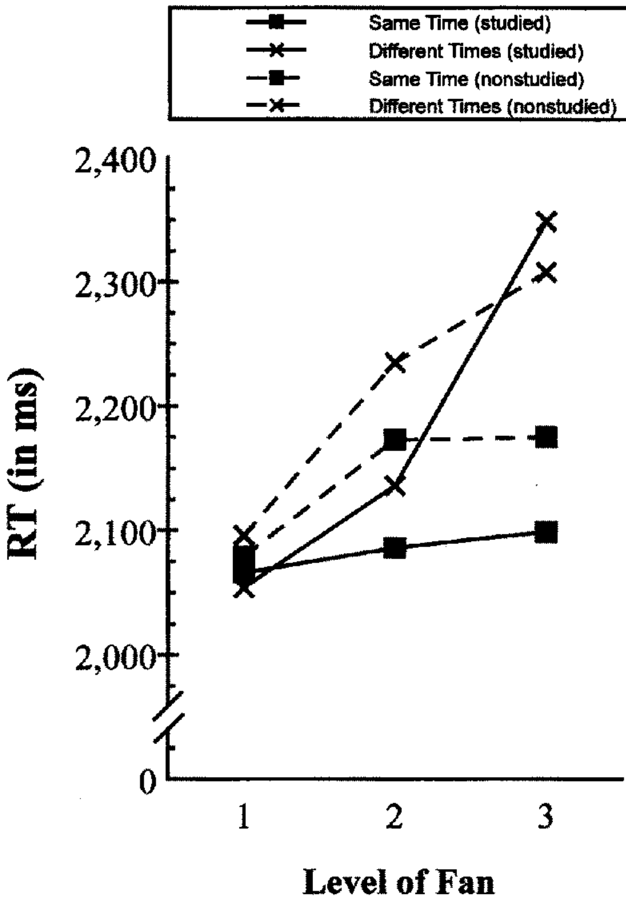

Figure 2. Response time (RT) data for Experiment 1.

Error rates. Although the primary data in these experiments are the response times, the error rate data also were considered. The mean error rate in Experiment 1 was 2.3%. These data were analyzed as the response time data were. There were two significant effects. First, the Studied–Nonstudied × Condition interaction was significant, $F(1, 47) = 5.33$, $MSE = 10.9$. For the studied probes, fewer errors were made in the same-time condition (1.8%) than the different-times condition (2.6%), but this difference was marginally significant, $F(1, 47) = 2.85$, $MSE = 16.6$, $p = .10$. In contrast, for the nonstudied trials a similar number of errors was made for the same-time (2.5%) and different-times conditions (2.1%), $F < 1$.

Second, the Studied–Nonstudied × Fan interaction was marginally significant, $F(2, 94) = 2.92$, $MSE = 10.4$, $p = .06$. Although there was a general increase in error rate with increased fan level for the studied probes (Fan Level 1 = 1.6; Level 2 = 2.4; Level 3 = 2.7%), $F(2, 94) = 2.66$, $MSE = 11.3$, $p = .08$, there was no such consistent pattern for the nonstudied probes (Fan Level 1 = 2.4; 2 = 1.6; 3 = 3.0%), $F < 1$.

It is unclear how such significant effects should be interpreted. The pattern of errors is consistent with the response time data for the studied probes, whereas the error rate data for the nonstudied probes do not show such consistency. However, because of the generally low error rate, the weakness of these effects, and the fact that they are not repeated in the subsequent experiments, little weight is given to them. All of the error rate data for all of the cells are provided in the Appendix for interested readers.

Discussion

A clear time-based organization was observed in Experiment 1. There was a fan effect for the different-times condition but not for the same-time condition. This is consistent with the idea that people were integrating information into situation models on the basis of common time periods. When a set of facts that shared an event concept could be integrated into a common situation model in the same-time condition, then no fan effect was observed. In contrast, when a set of facts sharing an activity concept in common in the different-times condition could not be integrated, then during the retrieval of any one of these facts, the related but irrelevant situation models were activated, generating interference. Thus, a fan effect was observed. This is consistent with the idea that a common time frame is needed to integrate information into a situation model.

It may be noted that there appears to be a small but nonsignificant fan effect for the same-time condition, especially for the nonstudied probe data. This is in contrast to research using spatial materials (e.g., Radvansky & Zacks, 1991) in which the fan effect is absent. One likely explanation for this discrepancy is that people may find it more difficult to use a temporal organization than a spatial organization (e.g., Carroll, Thomas, & Malhotra, 1980), perhaps because it is easier to use strategies such as imagery for spatial information than for temporal information. As such, the people may have found it somewhat more difficult either to notice that the information could be organized by time or to actually create a temporally based structure. Even if this were the case, it is important to note that any such difficulty on the part of our participants does not obscure the main finding: namely that there was substantial evidence for integration in the same-time condition but not in the different-times condition.

Experiment 2

The purpose of Experiment 2 was to extend the findings of Experiment 1, namely the observation of a time-based organization, to a different temporal marker by using a slightly different methodology. As mentioned earlier, time frames can be established relative to "anchor" events, such as "when the camera flashed" as was done in Experiment 1, in which different time periods were marked with different events. In addition, time periods can be established relative to the time of utterance (Reichenbach, 1947) through the use of tense morphemes. In Experiment 2 the time periods were marked by the verb tense of the study sentences. There were three time periods of interest: past, present, and future. This makes for a more subtle means than using different events to test for the organization of the information based on temporal markers.

In Experiment 2 there were either one or three activities associated with a single person. In the same-time condition, all of the activities that a person performed were described with the same verb tense (e.g., all past tense). In contrast, in the different-times condition, each activity was described with a different verb tense (i.e., one past, one present, and one future). Note that in this design the same activities are used in both the same-time and different-times conditions, unlike Experiment 1, in which the different conditions had different materials (i.e., one activity and three events in one condition and vice versa for the other).

For those person concepts that had three activities associated with them, each activity was from a different class: facial, manual, or mental. *Facial* activities involved the person manipulating some part of his face, such as whistling a tune or smiling. *Manual* activities involved the person using his hands, such as writing a check or carrying a package. Finally, *mental* activities were ones that a person could perform in addition to a facial and manual activity, such as checking the time or daydreaming. This use of activities allowed people to interpret the information as being simultaneous even though this was never explicitly mentioned. It should also be noted that this categorization of the activities was never mentioned to the participants in the experiment. As such, we could assess the strength of the bias to organize information into situation models based on time. That is, although the activities are integratable, there is not necessarily the sense of simultaneity that was present in the materials used for Experiment 1. Rather, in Experiment 2, the tense marker provides the means of accomplishing this integration. Again, the prediction of the situation model view is that more retrieval interference (a greater fan effect) will be observed for the different-times condition than the same-time condition.

As noted in the *Method* section of Experiment 1, to generate the nonstudied probes the person concepts were yoked with the activity concepts. This was done in Experiment 1 to focus participants' attention on the association between the activity and event concepts. There was no need to create such a focus in Experiment 2 because there were only two critical concepts in the study sentences. Thus, the re-pairing of person and activity concepts was explicitly manipulated in the construction of the nonstudied sentences; this was also done in Experiment 3.

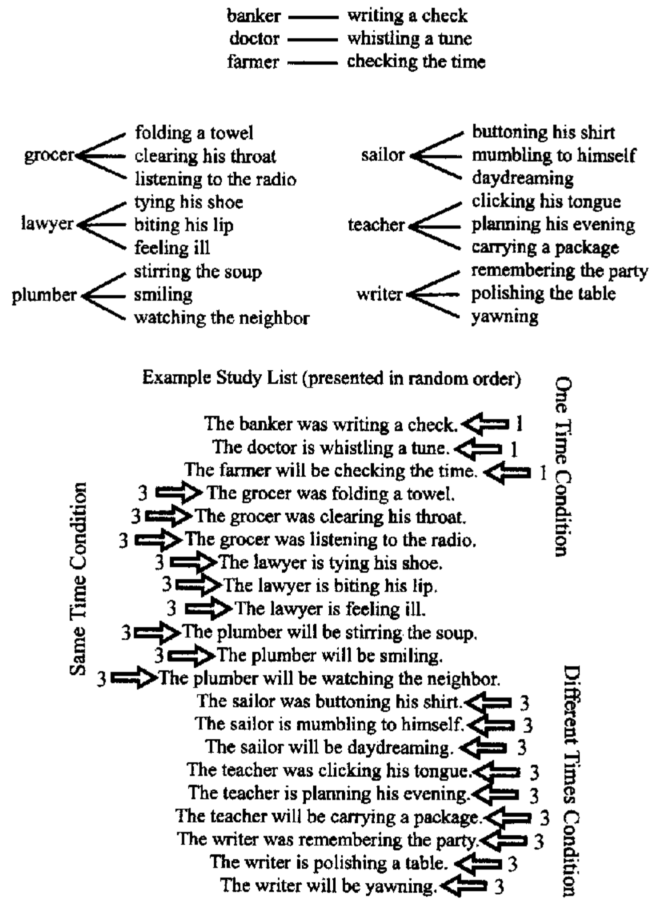

Figure 3. The structure of the study list concept associations of a hypothetical participant in Experiment 2. Those sentences contributing to the one-time, same-time, and different-times conditions are marked on the sample study list along with the corresponding level of fan.

Method

Participants. Twenty-four people were recruited from the same populations as Experiment 1 and were given partial class credit for their participation. Five people were replaced for failing to finish the study.

Materials and procedure. For Experiment 2, there were 21 study sentences of the form "The [person] was/is/will be [activity]," such as "The banker was writing a check." There were eight person concepts drawn from Experiment 1, with the addition of the name "sailor." The activities were divided into three classes: manual, facial, and mental. This was done to allow for a person to perform more than one activity at a time and allow for situation model integration.

An illustration of the study list design as well as a sample study list is presented in Figure 3. The study lists were structured so that six of the person concepts were associated with three activities, thus placing them at Fan Level 3. Three of the people were each performing their three activities at the same time: One person was doing three activities in the past, one in the present, and one in the future. This set of facts composed the same-time condition. The other three people were performing their three activities at three different times. This set of facts composed the different times condition. For these six people, there was one activity of each type (i.e., one manual, one facial, and one other). The final set of three people were each performing only one activity, thus placing them at Fan Level 1. One person was doing an activity in the past, one in the present, and one in the future. The type of activity performed by these three people was rotated through the three time periods every three participants. This last set of facts served as the one-time Fan Level 1 control condition to assess the effects of integration (or not) on retrieval time.

The memorization phase was similar to Experiment 1. For the test portion, the name of the person was displayed. A number was displayed along with the person's name, indicating whether there were one or three activities associated with that person, and the participants typed in their responses. Feedback was provided concerning the accuracy of each response after the activity was typed in. If any incorrect responses were made, the computer displayed the entire set of activities for that person before moving on to the next person. Responses were recorded to a file for later analysis.

The recognition test was like that for Experiment 1. Nonstudied probes were generated by recombining people and activities within a condition. The verb tense for the person concepts never changed. So, for negative probes, a person was described as performing an incorrect activity at the right time but never the right activity at the wrong time. This was done to avoid having people focus their attention on surface-level features during the recognition test. It has been demonstrated that having people engage in shallow levels of processing, such as focusing on surface features, will decrease the likelihood that they will use situation models (e.g., Singer & Halldorson, 1996; Zwaan, 1994). Furthermore, altering the verb tense associated with a person would have drawn more attention to temporal information during the recognition test. As such, by not manipulating verb tense during recognition, any effects of temporal markers observed in the recognition test data can be more confidently attributed to the organization that occurred during learning. A total of 3.5% of the response time data were trimmed using the same procedure described in Experiment 1.

Results

Learning. Participants took an average of 8.1 ($SD = 2.4$) cycles to memorize the study sentences. An analysis of the learning rates for items in different conditions with regard to condition revealed no difference between the one-time (3.3) and same-time condition items (3.5), $t < 1$. However, there was a significant difference between the one-time and different-times condition (4.1), $t(23) = 2.52$, and the difference between the same-time and different-times condition was marginally significant, $t(23) = 2.15, p < .10$.

Response times. The response time results for Experiment 2 are summarized in Figure 4 and supported our predictions. Because the data from the one-time condition could not be divided into the same-time and different-times conditions, an ANOVA similar to those in Experiments 1 and 3 could not be used. As such, only planned comparisons were done. For the studied probes, responses for the different-times condition were slower than for the same-time, $t(23) = 3.34$, and one-time conditions, $t(23) = 3.18$, which were not significantly different from one another, $t(23) = 1.34$, $p = .19$. Thus, there is a fan effect for the different-times condition but not for the same-time condition. This suggests that people use time to establish a framework in which to construct a situation model and that facts that refer to a common time period can be integrated into a common situation model. The responses to the nonstudied probes did not significantly differ among the different-times, same-time, and one-time conditions, all $ps > .20$.

Error rates. The mean error rate in Experiment 2 was 2.9%. These data were analyzed as the response time data were. The only comparison that reached significance was the difference between the same-time (3.1%) and the different-times conditions (1.9%) for the nonstudied probes, $t(23) = 2.3$. Because there is no ready interpretation for this pattern, we think that it is likely due to random variation given the pattern of error rates overall (see Appendix).

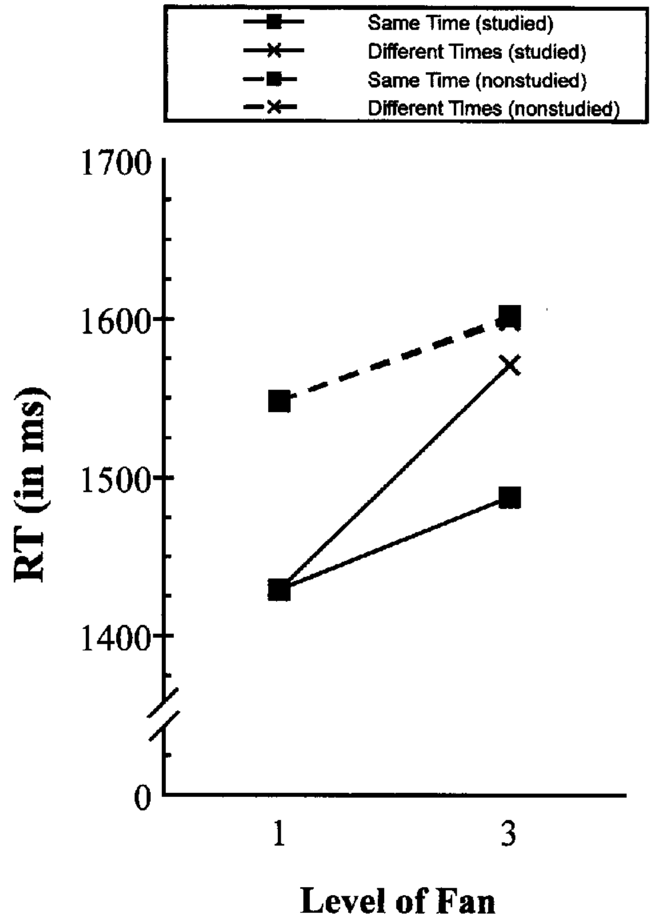

Figure 4. Response time (RT) data for Experiment 2.

Discussion

The results of Experiment 2 were consistent with those of Experiment 1 and the situation model view. For the studied probes, people showed a fan effect for person concepts associated with three activities that had different verb tenses. However, no significant fan effect was observed when the three activities had the same verb tense and thus could have taken place at the same time. Thus, the information seemed to be integrated into a single situation model in the former case but not the latter. Again, there appears to be a slight fan effect in the same-time condition, which we think reflects incomplete integration of the information when more abstract temporal relations rather than more concrete spatial relations are learned.

For the nonstudied probes, the data did not differ among the one-time, same-time, and different-times conditions, although there appears to be an increase in response time from Fan Levels 1 to 3. This is in contrast to the nonstudied probe data for Experiment 1, in which the nonstudied data showed a pattern similar to that of the studied data. Although the situation model view outlined earlier does not address this directly, we can provide an ad hoc explanation that is consistent with the theory. For the different-times conditions, although the activities are all described as occurring at different times, the same person is involved. Furthermore, the three verb tenses imply some sort of temporal sequence to the three situations. Because of this, people may associate the situation models representing this information together via some macro representation unit that integrates three situation models into a temporal string. So, when a person is verifying a different-times studied probe, some interference is observed because there are three situation models involved. However, when verifying a nonstudied probe, the information can be quickly rejected because it is not part of the same temporal string of models. As will be seen, in Experiment 3, in which a temporal sequence is not strongly implied, a similar pattern of response times is observed for both studied and nonstudied trials.

Experiment 3

Experiments 1 and 2 demonstrated that time can be an important basis for integrating information into situation models and that these situation models are used during memory retrieval. However, time is clearly not the only factor involved in regulating whether information can be considered to be part of the same situation model. In the event-indexing model (Zwaan, Langston, & Graesser, 1995; Zwaan & Radvansky, 1998), it is assumed that during reading people keep track of at least five aspects of a situation to help them decide whether a current description is part of the same or a different situation. These five dimensions are space, time, entities, causality, and intentionality.

In Experiments 1 and 2, the only aspect that was manipulated was time. Variations of causality and intentionality were kept at a minimum. As for entities, in Experiment 1, although a different person was mentioned in each study sentence, because there were few to no pre-experimental associations among these people to provide information about which people could and could not be together in the same situation, this aspect likely played no role in the organization of the situation models. In Experiment 2, the person concepts were repeated and could potentially be used to help with integration. However, the activities associated with a single person were created so that they did not conflict a priori with one another. As such, a single person could be engaged in them all at once. Finally, the spatial information was kept constant in Experiment 1 by telling participants that all of the people were at a party. Similarly, in an earlier study using the fan-effect paradigm, Myers, O'Brien, Balota, and Toyofuku (1984) examined the integration of stereotypical, script-like events that took place at a common setting, such as a baseball park or a restaurant. Myers and colleagues (p. 221) assumed that the setting would provide the theme for the set of events. In terms of the event-indexing model (Zwaan & Radvansky, 1998), their common spatial location, rather than a more abstract theme, provided for their integration. In Experiment 2, the activities were ones that could be done in the same spatial location.

The purpose of Experiment 3 was to demonstrate that although time is important, in and of itself it is not sufficient for situation model integration to occur. In Experiment 3, when multiple activities were associated with a single person, the verb tenses were kept the same as in the same time condition of Experiment 2. However, the activities associated with a person could be of one of two types. For half of the person concepts, the activities were like those used in Experiment 2 in that they could all be performed by the same person in the same spatial location. Because a person could do these all at the same time, thus allowing them to be integrated into a single situation model, these activities were defined as *integratable.* As in Experiment 2, it was expected that little or no interference would be observed for this integratable condition.

In contrast, for the other half of the person concepts, although time was held constant, the nature of the activities was such that it would be unlikely that a person could be engaged in them simultaneously or they could not be done in the same location. For example, it is unlikely that the same person would be "raking the leaves," "swimming a lap," and "playing the piano" all simultaneously as part of a single situation. Thus, they would be discontinuous on the entity and space dimensions, precluding the integration of the information into a situation model. Instead, because this information would be stored in separate situation models, these activities were defined as *nonintegratable* and were predicted to produce a fan effect. So, the prediction of the situation model view described here is that there should be a Condition $\times$ Fan interaction, with a clear fan effect for the nonintegratable condition but not in the integratable condition.

The construction of the materials in Experiment 3 did not involve manipulating verb tense in any of the conditions. As such, the issue of keeping the verb tense associated with a person the same for the nonstudied probes in Experiment 2 was not relevant in this experiment. Nonstudied probes were generated by rearranging activities from within the same set type (i.e., integratable or nonintegratable).

Method

Participants. Twenty-four people were recruited from the same populations as in Experiments 1 and 2 and were given partial class credit for their participation. Six were replaced for not completing the experiment and one for not following instructions.

Materials and procedure. For Experiment 3, the materials were generated in a manner similar to that in Experiment 2. People studied sentences of the form "The [person] was/is/will be [activity]," such as "The banker was stirring the soup," in which the verb tense was varied. However, there were some important differences. For all cases in which a person was described as doing three activities (Fan Level 3), all of the activities were described using the same verb tense. Three people were described as performing activities that could plausibly be done in the same location, such as "stirring the soup," "checking the time," and "biting his lip." These activities were a subset of those used in Experiment 2 and were used to generate the study sentences in the same manner as was done in Experiment 2. These sentences constituted the integratable condition. Three other people were described as performing activities that are very unlikely to be done concurrently, such as "feeding the dog," "playing pinball," and "stripping paint." These sentences constituted the *nonintegratable condition.* Each person concept was assigned a different verb tense,

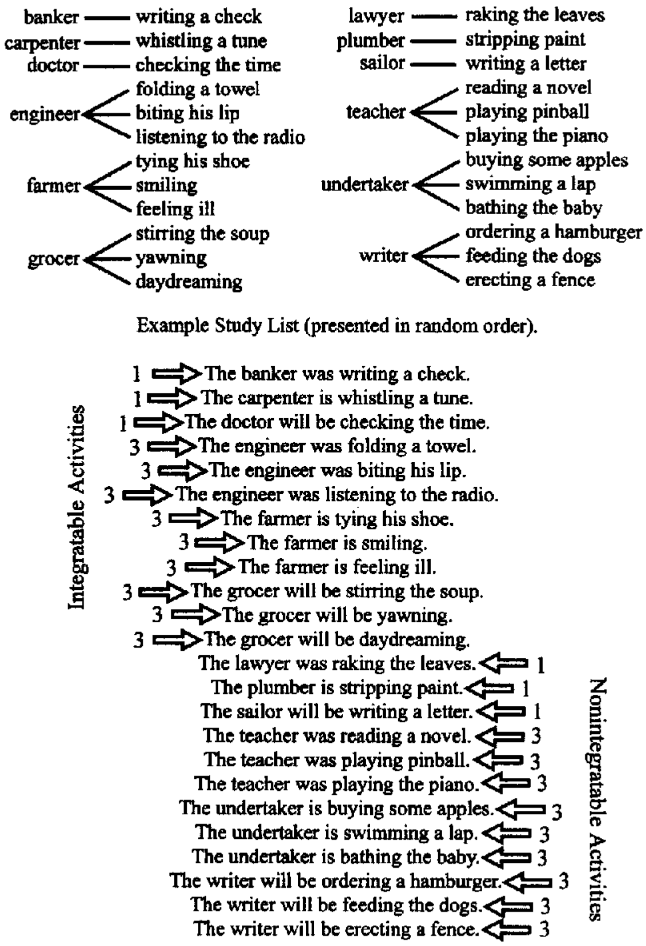

Figure 5. The structure of the study list concept associations of a hypothetical participant in Experiment 3. Those sentences contributing to the integratable and nonintegratable conditions are marked on the sample study list along with the corresponding level of fan.

such that each verb tense was represented once within each condition. In addition, there were six person concepts that had only a single activity associated with them (Fan Level 1); three were given activities from the integratable set, the other three from the nonintegratable set. These two sets served as the Fan Level 1 baselines for the integratable and nonintegratable conditions, respectively. Again, each verb tense was represented once within each of these sets. As such, there were 24 study sentences in Experiment 3. An illustration of the study list design as well as a sample study list is presented in Figure 5. The memorization and recognition test were similar to those in Experiment 2. Nonstudied probes were generated by recombining activities from the same set. That is, if a person was associated with a nonintegratable activity in the study sentences, other nonintegratable activities from sentences at the same level of fan were used for the nonstudied sentences. This was done to allow the nonstudied probes to be divided into integratable and nonintegratable conditions. A total of 2.7% of the response time data were trimmed.

Results

Learning. Participants took an average of 6.9 ($SD = 2.2$) cycles to memorize the study sentences. The data for when items were learned were submitted to a 2 (condition) × 2 (fan) ANOVA. The main effects of condition and fan were not significant, $F < 1$ and $F = 1.06$, respectively. However, there was a marginally significant interaction, $F(1, 23) = 4.10$, $MSE = 0.25$, $p = .06$. For the integratable activity items, people took more trials to learn the Fan Level 1 facts (3.4) than the Fan Level 3 facts (3.0). In contrast, for the nonintegratable activity items, there was no difference between the Fan Level 1 (3.2) and Level 3 facts (3.3). There does not appear to be a straightforward explanation for this.

Response times. The response time results of Experiment 3 are presented in Figure 6. The response time data were submitted to a 2 (studied–nonstudied) × 2 (condition: integratable vs. nonintegratable) × 2 (fan: 1 vs. 3) repeated measures ANOVA. Importantly, there was a significant Condition × Fan interaction, $F(1, 23) = 4.38$, $MSE = 85{,}137$. Simple effects tests showed a significant fan effect for the nonintegratable condition, $F(1, 23) = 6.81$, $MSE = 150{,}376$, but not for the integratable condition, $F < 1$. This suggests that people can use time to establish a framework in which to construct a situation model but that in order for integration to occur, the events must be consistent with a single situation. When they are not, no integration occurs.

In addition to the results of primary interest, the ANOVA

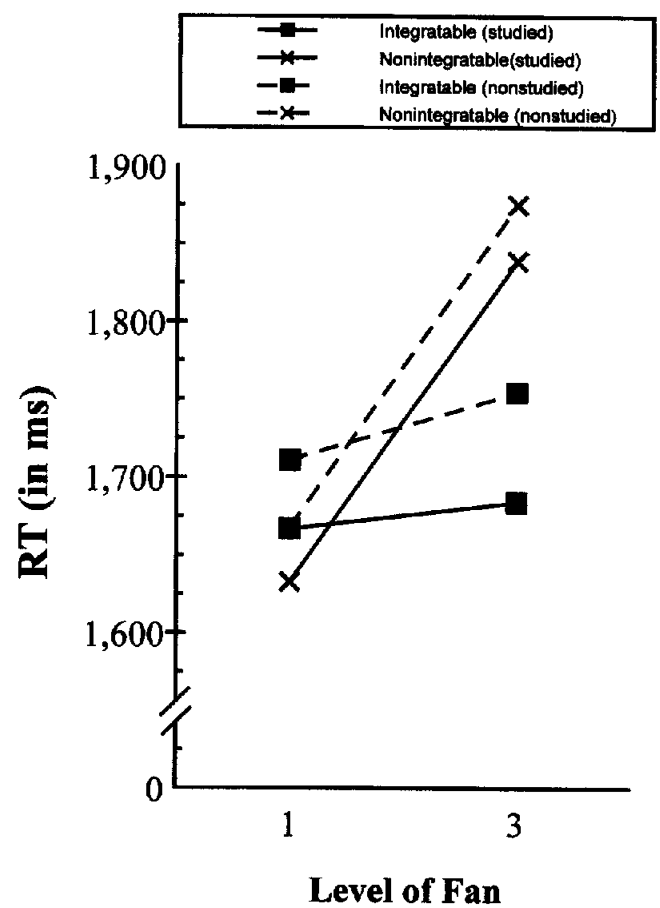

Figure 6. Response time (RT) data for Experiment 3.

also revealed a main effect of fan, $F(1, 23) = 7.13$, $MSE = 94{,}347$, with response times being faster for Fan Level 1 (1,670 ms) than Level 3 (1,788 ms). Finally, it should also be noted that the studied and nonstudied data showed a similar pattern. This reinforces our suggestion that the difference in the pattern of response times in Experiment 2 was due to the implicit suggestion to structure the information in the different-times condition into a temporal sequence, which was not present in Experiment 3.

Error rates. The mean error rate in Experiment 3 was 2.8%. These data were analyzed as the response time data were. There were no significant effects, all $ps > .10$.

Discussion

The results of Experiment 3 support those of Experiments 1 and 2 and the situation model view. Although a consistent verb tense was always paired with a person concept, our participants showed a fan effect only when the three activities were not consistent with a single situation in the world. However, no fan effect was observed when the activities potentially could be performed at the same time as part of the same situation. Therefore, people are able to use temporal cues to integrate actions into situation models, but time can be used only when the actions are also consistent with a single situation on other dimensions, including spatial location. A common time period in and of itself is insufficient for integration to occur. It is unclear at this time the degree to which temporal information in some form is necessary for integration.

General Discussion

The results of our experiments demonstrate that people can integrate information into situation models on the basis of common time periods. In particular, retrieval interference was observed when a set of facts that had a concept in common referred to different time periods, even when they were part of the same larger temporal context (the party in Experiment 1). The presence of different time periods blocks the integration of information into a situation model. Very little interference was observed when a set of related activities referred to the same time period. This was true both when the time period was specifically marked in relation to another event (Experiment 1) and when it was generally marked by a relative verb tense marker (Experiments 2 and 3).

This finding is consistent with the idea that in order for a situation model to be created, a person needs to establish a spatial–temporal framework in which to embed the situation (Radvansky et al., 1997; Radvansky & Zacks, 1997; Zwaan & Radvansky, 1998). Integration can occur when it is clear that two pieces of information refer to the same framework. When this is not possible, either because different time periods are involved or because of other constraints, such as a lack of a common spatial location or other mutual incompatibilities, then the information is separated into different frameworks and stored in separate situation models. People seem to use time as only one of several organizational tools, as shown by the presence versus absence of interference when activities cannot or can be integrated, respectively (Experiment 3). It is important to emphasize that the integration is occurring even though the information is presented in a random order and that there is no suggestion by the experimenter to organize the information in any way. As such, our data reflect the spontaneous creation of situation models. Thus, even with the relatively less naturalistic situation of our experiments, compared with normal reading, the influence of temporal information is still observed.

These findings are consistent with recent developments in situation model theory. One of the most recently developed accounts of situation model processing, the event-indexing model (Zwaan, Langston, & Graesser, 1995; Zwaan, Magliano, & Graesser, 1995), suggests that people keep track of temporal information as part of their understanding of the situation described by a text. According to that model, more processing is involved when there are breaks in any one of a number of dimensions that people monitor during comprehension. A break in temporal processing would occur when there is a large shift in the temporal framework. This would result in the transformation of the current situation model or a shift to a new situation model. This use of different temporal marking, either through events (Experiment 1) or verb tense (Experiment 2), would be consistent with this temporal dimension monitoring strategy in reading.

The event-indexing model further states that people keep track of multiple dimensions in addition to time and that a break in any one of these would result in increased processing due to situation model transformation or creation. So, in Experiment 3, when a consistent time period is present along with it being plausible that the activities can be done at the same time by the same person in the same spatial location (as can be inferred from the activities involved), a common situation may be implicated. However, when the activities cannot be done by the same person or in a common spatial location, although there is no inconsistency along the temporal dimension, there is inconsistency on these other dimensions. Because of this, separate situation models need to be constructed.

Experiments 1 and 2 demonstrated that language users are sensitive to temporal information in language. When people are prompted by linguistic cues to integrate information into situation models, they can do so. However, as Experiment 3 indicates, these cues can be overridden by world knowledge. Specifically, we found that people follow the linguistic cues only when the resulting representation is consistent with world knowledge. When actions are patently nonintegratable, because they cannot be simultaneously or consecutively performed by the same person in the same location, then people will not integrate these actions, even if linguistic cues suggest that they could be integrated. The relationship between linguistic cues and world knowledge in situation model construction is an important topic for further research.

The autobiographical memory literature suggests that time is not a very strong organizational factor in memory for events (Anderson & Conway, 1993; Thompson, Skowronski, Larsen, & Betz, 1996; Wagenaar, 1986). For example, Wagenaar's (1986) study of his own memory found that his recall of events was not significantly enhanced when they were cued by events that happened on the same day. Friedman (1993) concluded from this result that people do not integrate events on the basis of temporal contiguity. In contrast with this claim, Zwaan (1996, Experiment 3) found that temporal contiguity did facilitate the retrieval of events from long-term memory in a text comprehension paradigm. We believe that the present set of experiments provides a clue as to how to resolve this apparent contradiction. Specifically, events are integrated in memory on the basis of temporal information only when they meet two constraints: (a) they are temporally contiguous (e.g., as indicated by temporal markers or by direct experience) *and* (b) are otherwise integratable. The same-time events in our Experiments 1 and 2 as well as the temporally "close" events in Zwaan's (1996) Experiment 3 meet both constraints. In contrast, the different-times events in our Experiments 1 and 2 as well as the temporally "intermediate" and "far" events in Zwaan (1996) do not meet the first constraint. Additionally, the nonintegratable events in our Experiment 3 and the temporally contiguous events in Wagenaar's study do not meet the second constraint. In our Experiment 3 the events were nonintegratable into a single situation, and in the Wagenaar study, they were probably unrelated and possibly incompatible as well.

Some readers may note that in our experiments the order of the concepts was kept constant and may wonder whether our results are due to concept order. Although it is true that concept order was not manipulated here, in similar experiments that observed a differential fan effect, concept ordering was found to play no role in generating this effect (Radvansky, 1998; Radvansky & Zacks, 1991; Radvansky et al., 1996). Furthermore, in Experiment 1, the information was organized around the event concept, which came last in the study sentences, whereas in Experiments 2 and 3, the information was organized around the person concept, which came first in the study sentence, thus further discouraging the idea that an influence of concept ordering is of critical importance in producing the differential fan effect.

Comparing Situation Model and Theme-Based Propositional Network Accounts

The present experiments use the fan effect as a tool to illustrate how temporal information is involved in the organization of information into situation models. The fan effect was originally explained using propositional network models, such as the adaptive control of thought (ACT) family of models (Anderson, 1976, 1983, 1993). The basic idea was that information is stored in a complex of nodes (concepts) and links (associations). Although the present experiments do not provide a strong test between propositional network and situation model views (and were not designed to discriminate between them), because of the strong association of the term *fan effect* with propositional network models, we consider how this view might treat the current results (see also Radvansky, in press).

In previous fan effect research it has been suggested that when information is thematically related in some way, it may help serve to attenuate the fan effect. In this research, a "theme" has often been operationalized as a schema (Anderson, 1976; Reder & Anderson, 1980), or category (McCloskey & Bigler, 1980). One idea of how thematic information could serve to integrate information is that people may use preexperimental knowledge to form additional interconnections among the pairs of concepts in the study sentences (Jones & Anderson, 1987; Myers et al., 1984). That is, people can use semantic knowledge to establish additional connections between concepts. When activation spreads through the network, the additional pathways allow for an increased probability that a fact will be verified in a shorter period of time. These additional pathways can be either pathways that already existed in memory or new links created along with the direct association between concepts (i.e., inferences).

It seems unlikely that preexperimental links were involved in the present experiments as the concepts were randomly paired with one another. However, it is possible to interpret the data as reflecting the creation of additional inference pathways. Specifically, these extra links would be made in cases when the facts can be interpreted as being part of the same situation but not when they are interpreted as belonging to different situations. Thus, this account uses situational principles to guide when additional pathways are and are not created. In essence, this is a theory of situation models that assumes that the underlying model structure is propositional. The most clearly articulated exposition of this view was made by Myers et al. (1984). However, it should be noted that this specific view clearly predicts that fan effects will be smaller for nonstudied probes than studied probes. Yet, the opposite pattern was observed in Experiments 1 and 3. This could, in principle, be handled by further refinements of such a view.

In general, at this point in time it is difficult to say with any precision what the underlying structure of situation models is (Radvansky & Zacks, 1997). This is an issue that deserves closer examination in future work, if in fact it is answerable. Regardless of what the best description of the underlying nature of situation models turns out to be, the current research clearly shows that people are organizing their representations around situational principles.

Conclusions

According to our present analysis and that of Zwaan (1996), who used a completely different paradigm, we conclude that temporal markers in language serve as cues to the comprehender to integrate the events into a single situation model when they indicate temporal contiguity. Thus, people construct separate situation models for events when the temporal markers indicate different time frames. However, it should be noted that people do not blindly rely on temporal contiguity. If the events could be interpreted at the same time but are nonintegratable, such integration is unlikely to occur. Thus, information that allows for a common time frame is necessary in order to integrate information into a common situation model. However, temporal information is not sufficient. Because situation models are multidimensional, there are other factors such as causal and spatial information that can affect their organization.

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Appendix

Error Rates (in Percentages) per Cell for All Three Experiments

Condition	Fan level 1	Fan level 2	Fan level 3
Experiment 1			
Studied			
Same time	1.3	1.9	2.3
Different times	1.9	2.9	3.1
Nonstudied			
Same time	2.8	1.9	3.0
Different times	2.0	1.3	3.0
Filler trials	**2–3**[a]	**3–2**[a]	**3–3**[a]
Studied	4.1	3.5	2.8
Nonstudied	3.0	2.2	2.2
Experiment 2			
Studied			
One time	3.0		
Same time	3.7		
Different times	3.5		
Nonstudied			
One time	2.2		
Same time	3.2		
Different times	1.7		
Experiment 3			
Studied			
Integratable	2.7	2.4	
Nonintegratable	2.0	2.9	
Nonstudied			
Integratable	2.0	2.5	
Nonintegratable	2.3	2.4	

[a]See footnote 3.

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