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Temporal Order Relations in Language Comprehension

Elke van der Meer, Reinhard Beyer, Bertram Heinze, and Isolde Badel
Humboldt University at Berlin

The role of temporal orientation (chronological or reverse) and chronological distance (close, intermediate, or distant) in general event knowledge on language comprehension was examined. Experiment 1 used a relation-recognition paradigm in which the comprehension of a target event could be facilitated or disrupted by the temporal orientation implied by the prior information. Experiments 2 and 3 used a sentence–probe-recognition paradigm in which the temporal orientation, the stimulus onset asynchrony, and the chronological distance between the sentence event and the probe event were manipulated. The results demonstrated that readers used temporal information conveyed by their knowledge to construct situation models while comprehending sentences. The internal temporal dimension appeared to be directional and reflected the chronological distance between everyday events.

Temporal information in language allows the comprehender to locate in time the situations to which discourse refers. Temporal information is richly encoded in grammar and in the lexicon. Kintsch (1992) has pointed out that a syntax may be regarded as a set of processing instructions on how to construct situation models. Zwaan (1996) suggested that the same holds true for the semantics of time. Therefore, the main purpose of the present series of experiments was to assess how people interpret situations on the basis of temporal information not stated explicitly in the information presented but conveyed by the comprehender's knowledge stored in long-term memory (LTM).

The situation model is considered a mental model of the situation described by the given information, for example, by a text, and serves to integrate the information derived from the text with the reader's knowledge represented in LTM (van Dijk & Kintsch, 1983). Various sources of knowledge are used in the construction of situation models, such as knowledge of the world and about the language and personal experiences of the comprehender. Knowledge elaborations may be of many different types depending on the information presented but also on the comprehender's task and the resources available. There is now considerable evidence that comprehension of text involves the construction of situation models (e.g., Bower & Morrow, 1990; Kintsch, Welsch, Schmalhofer, & Zimny, 1990; Zwaan & Radvansky, 1998). Several studies also suggest that situation models influence the organization of information and its retrieval from LTM (Radvansky, Spieler, & Zacks, 1993).

The script-based situation model is one type of situation model. It refers to the representation of highly frequent sequences of events that occur in a common spatial–temporal framework. Kintsch and Mannes (1987) showed that these scripts (Schank & Abelson, 1977) are not fixed or fully elaborated preexisting knowledge structures that are retrieved for use. Instead, they are emergent structures, consisting of a skeleton, that is, an ordered list of episode names providing the basic information of the temporal sequence of the scriptural episodes. These structures are constructed in the context of their use.

The majority of studies on situation models have analyzed spatial relations. There has been comparatively less research on temporal relations. Several studies have investigated how people use temporal markers to construct situation models using reasoning (Schaeken, Johnson-Laird, & d'Ydewalle, 1996), comprehension (Anderson, Garrod, & Sanford, 1983; Carreiras, Carriedo, Alonso, & Fernandez, 1997; Zwaan, 1996), and memory-retrieval (Radvansky, Zwaan, Federico, & Franklin, 1998) paradigms. Such experiments have focused on two issues: first, how shifts in time encourage readers to either update a current model or shift to a new one, and second, how the organizational aspects of time can affect information integration into a single situation model.

However, the temporal location of a situation is not always stated explicitly in the information presented. In these circumstances, it has been proposed that the default assumption of comprehenders is that the order in which situations are reported corresponds to the situations' chronological order. This has been called the *iconicity assumption* (Fleischman, 1990; Hopper, 1979; Zwaan, 1996). Psycholinguistic research has provided empirical support for this assumption. Mandler (1986) found that discrepancies between the order of mention and chronological order of events led to longer reading times compared with sentences in which the reported order corresponded with the chronological order. This finding also corresponds to the more general theory of dynamic mental representations proposed by Freyd (1987). A dynamic mental representation is characterized by two criteria. First, the temporal dimension is inextricably embedded in the representation. Second, the internal temporal dimension is like the external time: directional and continuous. Thus, temporal information is considered to be an important dimension of all everyday LTM representations. For example, in the case of routine events the chronological order of events is assumed to be represented in

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Elke van der Meer, Reinhard Beyer, Bertram Heinze, and Isolde Badel, Humboldt University at Berlin, Berlin, Germany.

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Correspondence concerning this article should be addressed to Elke van der Meer, Department of Psychology, Humboldt University at Berlin, Oranienburger Street 18, 10178 Berlin, Germany. E-mail: vdMeer@rz.hu-berlin.de

memory. There is considerable evidence for this claim. Several investigators demonstrated the preference of the chronological order of routine events compared with either the reverse order or with a random order in using a variety of different paradigms (e.g., Beyer, van der Meer, Hagendorf, & Strauch, 1998; Friedman, 1990; Nelson & Gruendel, 1986; Noordman & Vonk, 1987; Sirigu et al., 1995).

The theory of dynamic mental representations assumes the temporal dimension not only to be an important component of routine events but also to be embedded in the mental representation of individual events. Van der Meer, Krüger, and Nuthmann (1999) tested this prediction. They presented event–feature pairs with temporal connectives (*before* and *after*) specifying the intended temporal orientation of items. The results demonstrated that chronological items (e.g., *after heating–warm*) were processed faster and with higher accuracy compared with reverse items (e.g., *before heating–cold*). Because the temporal connectives *before* and *after* are considered to be of identical semantic complexity (cf. Brent, 1989), they were not assumed to cause this superiority effect of chronological items (van der Meer, 2000). Rather, these findings are consistent with the theory of dynamic mental representations, which presupposes that comprehenders have mental representations about the external world that emphasize future time. Similarly, Kintsch (1998) discussed the influence of knowledge on constructing script-based situation models and assumed the associations among the elements that compose a script to be often unidirectional. Concerning the script of grocery shopping, "*going through the aisles* is associated with *going to the checkout counter*, but there is no link in the reverse direction" (Kintsch, 1998, pp. 84–85). This world knowledge of the chronological order of events is assumed to be used while comprehending language. Consequently, the hypothesis is that the comprehension process should be facilitated if the presented information and the activated knowledge strictly correspond: The present study tested predictions about the effect of discrepancies between chronological order of events and order of mention. Especially, it was examined whether there is a chronological orientation of general event knowledge that affects language comprehension. In addition, the influence of the distance of events on the assumed mental temporal dimension was analyzed. The term *distance* refers in this context to an ordinal measure (of the distance of the position of events on the mental temporal dimension).

Three experiments were carried out. In the first experiment, a recognition procedure was used. Frequently occurring sequences of events with identical strength of temporal relatedness between the predecessor and the successor of events were considered. The purpose of this experiment was to analyze whether the findings of van der Meer et al. (1999) can be generalized to pairs of events.

The second experiment was designed to verify the preferred temporal orientation of event knowledge in a more complex sentence context. Participants had to read a sentence describing a real-life event. Subsequently, a probe was presented also describing a real-life event. Participants had to recognize whether the probe had or had not occurred in the sentence. The false probes were either successor events (*chronological* probes) or predecessor events (*reverse* probes) of the sentence events, or they were unrelated events (*unrelated* probes). Specifically, the time interval (stimulus onset asynchrony; SOA) between the sentence and the probe was manipulated to influence the participants' elaborations of the sentences (Till, Mross, & Kintsch, 1988). The construction of meaning is a highly constructive and contextual process. Kintsch (1998) argued that the process of the construction of word meaning is completed in 300–350 ms, whereas 500–1,000 ms appear to be required for thematic inferences. Therefore, we hypothesized that with increasing SOA the influence of event knowledge on language comprehension should also increase.

The purpose of Experiment 3 was to investigate the influence of chronological distance (close, intermediate, or distant) of sentence events to false probe events on language comprehension. All events were within the boundaries of a script or scenario. There are two accounts that make contrasting predictions about the effects of chronological distance on recognizing whether the probe event had occurred in the sentence (cf. Zwaan, 1996). First, the scenario model (Anderson et al., 1983) suggests that readers construct situational models in discrete chunks, called *scenarios*. In doing so, readers use their event knowledge about the structure and lengths of various routines. All temporal intervals that are within the boundaries of a scenario should be integrated with identical difficulty. In consequence, there should be no effect of chronological distance whatsoever on reaction times (RTs) for temporally related false probes: close = intermediate = distant.

The strong iconicity account (cf. Zwaan, 1996) assumes that events that are contiguous in time may be easy to integrate. If readers can temporally locate each incoming event after the most recent event, the construction of the situation model should be facilitated. However, if such temporally related probe events had not occurred in the previously presented sentence, readers' correct rejection should be impaired. Furthermore, if a probe event in real life does not immediately follow the previously mentioned sentence event, the probe event may be more difficult to integrate. This would presumably introduce some extra processing load for the reader and would prompt the reader to reject the temporally related false probe. In consequence, the iconicity model predicts the following pattern of RTs for the critical false probes: close > intermediate > distant.

Experiment 1

The goal of Experiment 1 was to analyze whether the findings of van der Meer et al. (1999) with event–feature pairs can be extended to sequences of events. The experiment used a recognition paradigm. First, participants were given preinformation consisting of an individual event together with a temporal connective (*before* or *after*) that specified the experimentally intended temporal orientation of the event. Later, the target, a successor or predecessor event, was presented. Participants had to decide whether preinformation and target were related in a proper way. We hypothesized that if all mental representations of the external world emphasize future time (Freyd, 1987), items with a temporal orientation toward future time would be processed faster and more accurately than items with a temporal orientation toward past time.

Method

Participants. Forty-two psychology students of Humboldt University at Berlin participated in the experiment. Twenty-two students (17 female, 5 male; mean age: 23 years) participated in a pretest to examine the adequacy of the experimental materials. They received either course credit or a DM 20 (approximately $10) payment for participation. Twenty students

(17 female, 3 male; mean age: 25 years) participated in the main experiment. They received either course credit or a DM 10 (approximately $5) payment for participation.

Stimuli and materials. The word stimuli were generated in a controlled association experiment. The selected item pool consisted of 30 sequences of four events (A, B, C, and D; e.g., *bite off*, *chew*, *swallow*, and *digest*). Starting from either the first event in the sequence (A) or the last event (D), a second event from the sequence was combined. In this way chronological items (A–B; e.g., *bite off–chew*) and reverse items (D–C; e.g., *digest–swallow*) were constructed. The sequences of four events allowed us to strictly avoid word repetition. The word frequency (Corpus Nijmegen; Baayen, Piepenbrock, & Gulikers, 1995) was comparable for chronological and reverse items, $\chi^2(1, N = 60) = 1.04$, $p > .31$. The experimental materials were tested using four 7-point rating scales. The judgments did not differ between the chronological and reverse items with regard to following test criteria: (a) *temporal relatedness* as indicated by the controlled association frequency (i.e., the temporal succession was the instructed criterion for generating associations), $\chi^2(1, N = 60) = 0.16$, $p > .68$; (b) *item typicality* ($z = 0.78$, $p > .43$); (c) *event duration* in reality (first event [A vs. D]: $z = 0.34$, $p > .73$; second event [B vs. C]: $z = 0.47$, $p > .64$); and (d) *temporal distance* between the individual events in reality ($z = 0.33$, $p > .74$). Note that the strong temporal relatedness of stimuli does not imply their strong semantic relatedness. In an additional pretest it was shown that free associations corresponded with controlled associations mentioned above in merely 1.5% (successor associations) and 0.9% (predecessor associations). The difference between free successor and predecessor associations was not significant, $\chi^2(1, N = 60) = 0.20$, $p > .65$. That is, the temporal relatedness of the selected experimental stimuli is very strong; their semantic relatedness, however, is rather weak.

The experiment consisted of two item blocks, each containing 12 practice and 60 test items. Each item was composed of the preinformation and the target. The preinformation consisted of two components: the temporal connective *before* or *after* and an event (e.g., *bite off*); the target was an event (e.g., *chew*). The temporal order between the preinformation and the target could either correspond to the chronological order of events in reality (e.g., *after bite off–chew*), in which case the items were referred to as chronological items. Or, it could run against the chronological order, in which case the items were referred to as reverse items (e.g., *before digest–swallow*). Preinformation and target words consisted of three to five syllables. The chronological and reverse-item groups were controlled for the number of syllables. The experiment was run in German. To clarify the presentation, all of the examples have been translated to English. The original materials may be obtained from Elke van der Meer.

Design. The following independent variables were considered in the experiment (within subjects): SOA (200 ms and 1,000 ms) and temporal orientation (chronological and reverse). The participants were presented half of the items with an SOA of 200 ms (Block 1) and the other half with an SOA of 1,000 ms (Block 2). The block order and the item pool were switched between participants, who were randomly assigned to the resulting four versions. Preinformation and target were either related (50%) or not related in a proper way (50%). For related items, the temporal orientation between the preinformation and the target was varied: either corresponding to the chronological order (50%; e.g., *after bite off–chew*) or corresponding to the reverse order (50%; e.g., *before digest–swallow*). RTs and error rates were recorded as dependent variables.

Procedure. The participants received a written instruction. The experiment was carried out on an IBM-compatible microcomputer using the software Experimental Run-Time System (ERTS; Beringer, 1996). The preinformation was presented for either 200 ms or 1,000 ms, followed by the target. Participants had to decide as quickly and accurately as possible whether the target event described the situation as characterized by the preinformation in a proper way. If this was true, a right external button had to be pressed; if not, a left external button had to be pressed. In all experiments, participants were told to keep their index fingers on the *yes* and *no* buttons the whole time. The target remained on until a response was recorded, at which time the screen was cleared for 3,000 ms before the next trial began. Within both item blocks, the item order was randomized.

Results

The relevant RT data are displayed in Figure 1. Because the hypotheses refer to the related items, the distractors were excluded from the statistical analysis. In all experiments, the mean RTs were computed after excluding false responses and discarding outliers. Outliers were defined as RTs exceeding two standard deviations but excluding distractor items. None of the outliers eliminated from the analyses were counted as errors. In Experiment 1, this trimming procedure dropped 4.6% outliers out of the data. A 2 (SOA: 200 vs. 1,000 ms) × 2 (temporal orientation: chronological vs. reverse) repeated measures analysis of variance (ANOVA) was performed. In all experiments, F_1 refers to tests in which the error term was based on participant variability, and F_2 refers to tests in which the error term was based on item variability. In all analyses, a rejection criterion of $p < .05$ was assumed.

RTs. The analysis revealed statistically significant main effects of all independent variables with shorter RTs for chronological items than for reverse items, $F_1(1, 19) = 46.20$, $MSE = 56{,}173$; $F_2(1, 29) = 22.13$, $MSE = 157{,}503$, and longer RTs for the 200-ms SOA condition compared with the 1,000-ms SOA condition, $F_1(1, 19) = 14.09$, $MSE = 193{,}373$; $F_2(1, 29) = 13.96$, $MSE = 249{,}366$. The interactions of both variables were not significant ($F_1 < 1$, $F_2 < 1$).

Error rates. The analysis of error rates revealed a statistically significant main effect of the independent variable temporal orientation with less errors for chronological items than for reverse items, $F_1(1, 19) = 40.09$, $MSE = 97.78$; $F_2(1, 29) = 15.20$, $MSE = 386.90$. There was a significant main effect of SOA by items, $F_2(1, 29) = 6.12$, $MSE = 139.54$, but not by participants, $F_1(1, 19) = 2.28$, $MSE = 255.44$, $p > .15$, with more errors in the 200-ms SOA condition (chronological items: 14%; reverse items: 28%) than in the 1,000-ms SOA condition (chronological items: 8.67%; reverse items: 22.67%).

There was no significant interaction between temporal orientation and SOA, neither by participants nor by items ($F_1 < 1$, $F_2 < 1$).

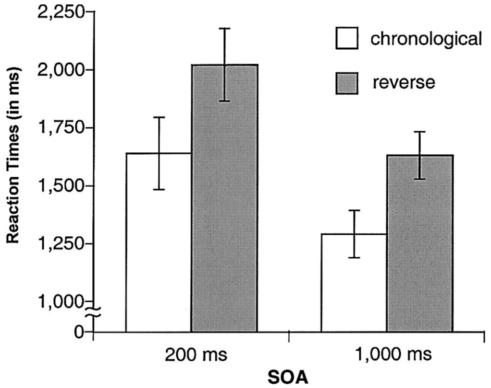

Figure 1. Temporal orientation—reaction times (in milliseconds) required to accept correct targets depending on stimulus onset asynchrony (SOA) and temporal orientation for Experiment 1. Standard error bars are included.

Discussion

The results clearly suggest that there is a beneficial effect of chronological order on the recognition of relatedness between real-life events. Chronological items were processed faster compared with reverse items. The error percentages displayed a pattern similar to that of the RTs, indicating that there was no speed–accuracy trade-off. The preferred chronological orientation of event sequences found in Experiment 1 supports the findings of van der Meer et al. (1999), which analyzed the access to event–feature pairs in semantic memory. An SOA of 1,000 ms helped in speeding up and improving the recognition of relations compared with an SOA of 200 ms. Thus, the temporal framework, that is, the script-based situational model established during the processing of the preinformation, appeared to be based on the chronological order of events in reality. Events related to the preinformation by chronological relations were first of all preactivated in semantic memory. These findings raised the question of whether a more naturalistic and complex comprehension task could further enlarge the influence of event knowledge on language comprehension.

Experiment 2

The purpose of Experiment 2 was to address this question empirically. This was done by embedding the events in sentences. For example, the preinformation–target pair *after strike–burn* could be changed to the sentence–probe pair *The housewife strikes the matchstick–burn*. This change eliminated the temporal information explicitly stated by the temporal connective. The sentence described nothing more than the event. The second critical event was given in the probe. Participants had to recognize whether the probe had occurred in the sentence. The idea was that sentence comprehension involved the construction of script-based situation models. First, if the general event knowledge contained temporal information, it should have been accessed in sentence comprehension. Second, if this knowledge was directed toward future time, future-oriented events should have been available and integrated into the situation model faster compared with past-oriented events. Third, the longer the sentence presentation time, the larger the effects of knowledge on constructing the script-based situation model were expected to be. Consequently, false probes (i.e., probes that had not occurred in the sentence) that were related to the sentence should have been rejected significantly slower than false probes not related to the sentence.

In addition and more precisely, for all false probes a significant SOA × Probe Type interaction should have appeared. For very short SOAs, on the basis of Till et al.'s (1988) findings, performance should not have differed for unrelated, chronological, and reverse probes. For medium SOAs, elaborate processing was assumed. Therefore, an increase in rejection times for chronological probes compared with reverse and unrelated probes was expected. For long SOAs, reverse probes were also assumed to be accessible in the comprehenders' memory. Thus, rejection times should not have differed for chronological and reverse probes. For the unrelated probes, shorter rejection times were predicted compared with chronological and reverse probes.

Method

Participants. Two hundred ten psychology students from Humboldt University at Berlin participated in the experiment. None of these students had participated in Experiment 1. Thirty students participated in a pretest of the experimental materials (21 female, 9 male; mean age: 24 years). Fifty students participated in the very short SOA condition (36 female, 14 male; mean age: 23 years), 70 participated in the medium SOA condition (52 female, 18 male; mean age: 23 years), and 60 participated in the long SOA condition (46 female and 14 male; mean age: 23 years). All were fluent German speakers. They received either course credit or a DM 10 (approximately $5) payment.

Stimuli and materials. Stimulus materials consisted of 90 experimental items and 90 filler items, each containing a sentence–probe pair. The filler items were correct items with respect to the occurrence of the probe word in the previously presented sentence and required a "yes" response. The experimental items were false items with respect to the occurrence of the probe word in the previously presented sentence and required a "no" response.

The stimuli (sequences of three events; A, B, and C) were constructed in the following way. Participants were presented a verb naming an event (B; e.g., *burn*). They were asked to provide a predecessor event (A; e.g., *light*) and a successor event (C; e.g., *extinguish*). Half of the participants had to associate the successor event first and the predecessor event second; the other half had to provide the predecessor event first and the successor event second. The controlled association frequency (i.e., temporal succession was the instructed criterion for generating associations) between the middle element in such sequences of three and its predecessor and successor did not differ, $\chi^2(1, N = 60) = .16$; $p > .68$. Subsequently, the experimental materials were confirmed in a rating task. Participants rated each item on four scales. The judgments did not differ between the chronological and reverse items with regard to following criteria: (a) typicality (ranging from 0 [*very low*] to 8 [*very high*])—the relation typicality between the middle element and its predecessor and successor did not differ ($z = -0.24$, $p > .80$); (b) duration (ranging from 0 [*very short*] to 8 [*very long*])—the duration in reality for the individual predecessor event and the successor event of the middle element was the same ($z = -0.45$, $p > .66$); (c) temporal interval (ranging from 0 [*very short*] to 8 [*very long*])—the time interval that elapsed when the first event in reality had been completed but the following one had not yet begun was the same between predecessor and successor in the sequence of three ($z = -0.54$, $p > .58$); and (d) emotional valence (ranging from 0 [*very pleasant*] to 8 [*very unpleasant*])—the emotional valence for the predecessor and the successor within the sequences of three did not differ ($z = -0.65$, $p > .51$).

These sequences of three events were used to create sentence-probe pairs, with one event being part of the sentence and the other serving as probe. For each of 15 sequences of three events, four sentence-probe pairs were created by manipulating the independent variables relatedness (related or unrelated) and temporal orientation (chronological or reverse). The temporal orientation was manipulated in two different ways. For Type A materials, a constant sentence containing the middle element of a sequence of three events (e.g., *fall*) was combined with a probe event, either temporally preceding (e.g., *slip*) or succeeding (e.g., *rise*) the sentence event. The sentences were of the following form (in German): preposition, adjective, noun (location), noun (actor), and verb (event). For example, *It is possible to fall down on smooth ground.* In contrast, for Type B materials, the middle element of a sequence of three events was used as a constant probe event (e.g., *wash*) combined with a sentence containing an event either temporally preceding (e.g., *The boy soils his shorts.*) or succeeding (*The clothes dry in the sun.*) the probe event. The sentences were of the following form: noun (actor), verb (event), and noun (object or location). An equal number of unrelated sentence–probe pairs was added. They were constructed with each event of the sequence of three (e.g., *wash*) serving as probe combined with an unrelated sentence (e.g., *The children dream at school*). Thus, for both the Type A and Type B materials, there were 30 related and 30 unrelated sentence–probe pairs. The related and unrelated items were controlled for the number of words and syllables. An example of the combination of sentence–probe pairs for Type A and Type B materials is presented in Table 1.

An effort was made to avoid biasing word or strategy effects. Therefore, 30 additional experimental items were constructed. These contained probes that were false with respect to either the adjective, the noun, or the conjugated verb of the previously presented sentence (e.g., *The poet recites his poem–drives*). The 90 filler items had the same sentence form and length as the experimental items. The probes were either verbs, adjectives, or nouns that had occurred in the previously presented sentences.

In a pretest, the items were carefully tested. For filler items and unrelated items, participants rated the typicality of all sentences on a scale ranging from +2 (*most typical*) to −2 (*least typical*). The sentences ranked high on typicality (+2). For related and unrelated items, participants rated the relatedness, the typicality, and the chronological order of all sentence–probe pairs. The related items ranked high on relatedness, typicality, and chronological order (+2); the unrelated items ranked low on all three criteria (−2).

Design and procedure. Relatedness (related or unrelated) and temporal orientation for related items (chronological or reverse) were within-subjects variables; SOA (average: 900, 1,200, and 3,000 ms) was a between-subjects variable. There were two dependent variables in the experiment: RTs and error rates for the probes.

Trials were randomized with one constraint: The items of the same sequence of three events were never adjacent to one another in the presentation. The participants were assigned randomly to the three SOA conditions, and within each of those conditions half were assigned randomly to the Type A materials and half were assigned to the Type B materials. There was no significant effect of the two types of experimental materials ($F_1 < 1$, $F_2 < 1$). The experiment was run on an IBM-compatible microcomputer using a program written in Borland Pascal 7.0. Responses were made with the appropriate index fingers by pressing the *y* and the *m* keys on the keyboard, which were marked *no* and *yes*, respectively. The participants were tested individually.

To analyze the integration of event knowledge in sentence comprehension and to adapt the sentence presentation times to the individual participant's characteristics, we measured each participant's mean motor RTs and mean reading times in two pretests. The sentences presented in these pretests had the same form and length as the sentences in the recognition task. The motor RT (M = 330 ms) and the reading time (M = 1,337 ms, including motor RT) data did not differ between the three participants' samples (motor RT: $F[2, 177] = 1.20$, MSE = 1,725, $p > .31$; reading time: $F[2, 177] = 1.19$, MSE = 202,820, $p > .30$). The three SOA conditions were created in the following way: In the very short SOA condition (about 900 ms), each sentence was presented for about 700 ms, followed by a masking interval for 200 ms. Thus, the sentences were presented for about 300 ms shorter than participants needed to carefully read them for comprehension. This was done strictly to reduce effects of general event knowledge on sentence processing. In the medium SOA condition (about 1,200 ms), each sentence was presented for about 1,000 ms, followed by a masking interval for 200 ms. This presentation time corresponded to the participants' standard reading time. In the long SOA condition (about 3,000 ms), each sentence was also presented for about 1,000 ms, followed by a masking interval for 2,000 ms. By extending this interval, we supported elaborate sentence processing. There was another way to generate the long SOA condition, namely, by prolonging the sentence presentation time. It was decided not to do so because this would have directed participants' attention to sentence rehearsal instead of elaboration.

Table 1
Examples for Critical Items of Experiment 2

Temporal orientation	Sentence	Probe word
	Type A	
Chronological	It is possible to fall down on smooth ground.	Get up
Unrelated	It is possible to indicate a serious mistake.	Get up
Reverse	It is possible to fall down on smooth ground.	Slip
Unrelated	It is possible to indicate a serious mistake.	Slip
	Type B	
Chronological	The boy soils his shorts.	Wash
Unrelated	The hunter looks at the rabbit.	Wash
Reverse	The clothes dry in the sun.	Wash
Unrelated	The children dream at school.	Wash

Directly afterward the probe was presented. The participant's task was to read the sentence and the probe and to decide as quickly and accurately as possible whether the probe had occurred within the sentence. The RT was measured from the presentation of the probe until the participant's button stroke. After a delay of 2,000 ms the next trial began. The experiment started with 12 practice trials (6 experimental items and 6 filler items) followed by 180 test trials. On the practice trials, immediate feedback was given. No feedback was given during the test trials.

Results and Discussion

Only the data from experimental items were analyzed. The data from filler items were omitted because they did not address the question asked in this experiment. The outliers-trimming procedure dropped 2% of outliers out of the data. Because the error rate was only 1.8%, the statistical analyses of the errors were omitted. The relevant RT data are displayed in Figure 2.

First, a 2 (relatedness) × 2 (temporal orientation) × 3 (SOA) within-subjects ANOVA was carried out. It revealed significant main effects of all independent variables, relatedness, temporal orientation, and SOA, with shorter RTs for unrelated items, $F_1(1, 177) = 30.48$, MSE = 2,328; $F_2(1, 87) = 23.40$, MSE = 1,395, shorter RTs for reverse items, $F_1(1, 177) = 5.53$, MSE = 2,105; $F_2(1, 87) = 3.26$, MSE = 2,408, $p = .07$, and longer RTs for longer SOAs, $F_1(2, 177) = 7.37$, MSE = 74,154; $F_2(2, 87) = 53.89$, MSE = 5,250. Further, analysis produced statistically significant interaction effects of relatedness and SOA, $F_1(2, 177) = 8.23$, MS = 19,166; $F_2(2, 87) = 10.50$, MS = 14,649, as well as of relatedness and temporal orientation, $F_1(1, 177) = 6.78$, MSE = 1,933; $F_2(1, 87) = 6.28$, MSE = 1,106. Most important, the three-way interaction was significant, $F_1(2, 177) = 5.84$, MS = 11,293; $F_2(2, 87) = 3.96$, MS = 4,381.

In a second step, a 2 (temporal orientation) × 3 (SOA) ANOVA was performed on the related items. There was a significant main effect of temporal orientation, both by participants, $F_1(1, 177) = 9.41$, MSE = 2,631, and by items, $F_2(1, 87) = 8.82$, MSE = 3,247, with longer RTs for chronological items. There was also a significant main effect of SOA, both by participants, $F_1(2, 177) = 9.25$, MSE = 41,576, and by items, $F_2(2, 87) = 65.60$, MSE = 1,677. In addition, the two-way interaction between both variables was significant, $F_1(2, 77) = 5.31$, MS = 13,948; $F_2(2, 87) = 3.16$, MS = 5,296.

The results of Experiment 2 clearly suggested that relatedness between sentences and probes influenced RTs. Most important, the effect of relatedness on rejection times varied by SOA condition. For short SOAs, chronologically related (710 ms), reversely related (709 ms), and unrelated items (708 ms) were rejected equally fast (chronological–reverse: $F_1 < 1$; $F_2[1, 29] = 1.08$, MSE =

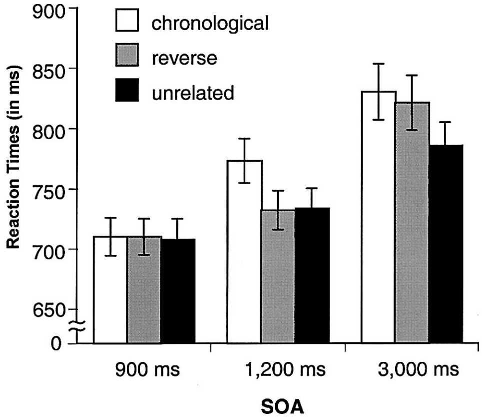

Figure 2. Temporal orientation—reaction times (in milliseconds) required to reject false probes depending on stimulus onset asynchrony (SOA) and temporal orientation for Experiment 2. Standard error bars are included.

1,654, $p > .31$; chronological–unrelated: F_1 and $F_2 < 1$; reverse–unrelated: F_1 and $F_2 < 1$). For medium SOAs, there was an advantage of unrelated (734 ms) and reverse items (732 ms) on rejection times compared with chronological items (773 ms; chronological–reverse: $F_1[1, 69] = 16.66$, $MSE = 3{,}445$; $F_2[1, 29] = 32.75$, $MSE = 713.41$; chronological–unrelated: $F_1[1, 69] = 21.31$, $MSE = 2{,}938$; $F_2[1, 29] = 19.84$, $MSE = 1{,}068$; reverse–unrelated: F_1 and $F_2 < 1$). In contrast, for long SOAs, chronological (830 ms) and reverse items (821 ms) were functionally equivalent and rejected slower compared with unrelated items (787 ms; chronological–reverse: F_1 and $F_2 < 1$; chronological–unrelated: $F_1[1, 59] = 16.83$, $MSE = 2{,}664$; $F_2[1, 29] = 12.22$, $MSE = 1{,}971$; reverse–unrelated: $F_1[1, 59] = 20.91$, $MSE = 2{,}272$; $F_2[1, 29] = 30.42$, $MSE = 995.69$).

Thus, Experiment 2 replicated Experiment 1, using a more complex sentence context. For medium SOAs, chronologically related probe events were accessed faster compared with reversely related probe events, resulting in slower rejection times. In addition, the influence of elaborate processing on sentence comprehension was demonstrated. Restricted SOA conditions prevented readers from integrating event knowledge in script-based situation models. Extensive SOA conditions, however, helped in integrating background knowledge, namely, past-oriented events, which were not accessed with medium SOAs. Thus, the manipulation of SOA between sentence and probe influenced not only the ease with which the sentence was processed but also the result of the comprehension process. The findings provide further support for the view that the effect observed here is an effect of general event knowledge and not an effect of linguistic devices (temporal connectives in Experiment 1).

Experiment 3

Experiment 3 was designed to provide an extension of Experiment 2. In this experiment, another pool of items was used in an effort to explore the effect of chronological distance between events on sentence comprehension. The paradigm was the same as in Experiment 2. As discussed in the introduction, two models were identified that make contrasting predictions about the effects of chronological distance on the mental representation and comprehension of sentence–probe pairs. According to the scenario model, there should have been no effect of chronological distance on RTs of false probes, if all events mentioned were within the boundaries of a script. According to the strong iconicity account, however, an effect of the chronological distance of events should have been expected. In Experiment 3, those contrasting predictions were tested.

Method

Participants. Thirty-four psychology students from Humboldt University at Berlin participated in the experiment (21 female and 13 male; mean age: 23 years). They received either course credit or DM 10 (approximately $5) payment. None of them had participated in Experiments 1 or 2.

Stimuli and materials. Stimulus materials consisted of 240 experimental items and 240 filler items, each containing a sentence–probe pair. The stimuli were selected from the item pool of Experiment 1. It consisted of 16 sequences of four events: A, B, C, and D. For both the first event (A) and the last event (D) in the sequence, short sentences were created. The sentences were of the following form: noun (actor), verb (event), adjective, and noun (object). In addition, two sentences of the same form and length were created that did not contain any event of the sequence. These four sentences were combined with the three remaining events of the sequence resulting in 12 sentence–probe pairs. This was done for all 16 sequences of events, resulting in 192 items. This combination provided experimental items in which the following three independent variables were manipulated: temporal relatedness between sentence and probe (related and unrelated), temporal orientation between sentence event and probe event (chronological and reverse), and chronological distance between sentence event and probe event (close, intermediate, and distant). In addition, 48 experimental items were created to avoid biasing word or strategy effects. These items also consisted of sentence–probe pairs. However, the probes were false with respect to either the noun or the adjective of the previously presented sentence. An example of the combination of conditions composing experimental items is presented in Table 2.

The 240 filler items had the same sentence form and length as the experimental items. The probes were either nouns, adjectives, or verbs that had occurred in the previously presented sentences.

Table 2
Examples for Critical Items of Experiment 3

Condition	Sentence	Probe word
Chronological—close	The boy bites off the juicy apple.	Chew
Unrelated	The hunter shoots the deadly arrow.	Chew
Chronological—intermediate	The boy bites off the juicy apple.	Swallow
Unrelated	The hunter shoots the deadly arrow.	Swallow
Chronological—distant	The boy bites off the juicy apple.	Digest
Unrelated	The hunter shoots the deadly arrow.	Digest
Reverse—close	The stomach digests the food.	Swallow
Unrelated	The worker uses up the material.	Swallow
Reverse—intermediate	The stomach digests the food.	Chew
Unrelated	The worker uses up the material.	Chew
Reverse—distant	The stomach digests the food.	Bite off
Unrelated	The worker uses up the material.	Bite off

Design and procedure. The experiment was a 2 (temporal relatedness) × 2 (temporal orientation) × 3 (chronological distance) within-subjects factorial design. The 480 items were split into two blocks. Each participant studied only one block. There was no significant effect of the experimental materials (Block 1 vs. Block 2: $F_1 < 1$, $F_2 < 1$). In addition, there were no significant interactions between experimental and any other variables of the design.

A set of 16 practice trials (8 experimental items and 8 filler items) was provided to familiarize the participants with the task. On the practice trials, immediate feedback was given. The participants were tested individually. They were instructed that sentences and probes would be repeated several times but never in the same combination.

In two pretests, each participant's mean motor RTs and mean reading times (including the motor RTs) were measured. For each participant, the sentence presentation time was individually adjusted by calculating the difference between the reading and the motor RTs. Within the sample, the mean motor RT was 338 ms and the mean RT was 1,625 ms. Thus, the mean sentence presentation time was 1,287 ms (1,625 ms − 338 ms). All other aspects of the procedure were the same as in Experiment 2.

Results and Discussion

Only the data from experimental items were analyzed. The outliers-trimming procedure dropped 2.1% of outliers out of the data. Because the error rate was only 1.4%, the statistical analyses of the errors were omitted. The relevant RT data are displayed in Figure 3.

An ANOVA revealed statistically significant main effects of the variables temporal relatedness, $F_1(1, 33) = 53.40$, $MSE = 3{,}457$; $F_2(1, 15) = 58.45$, $MSE = 1{,}277$; and chronological distance, $F_1(2, 66) = 12.51$, $MSE = 2{,}831$; $F_2(2, 30) = 7.13$, $MSE = 1{,}658$. Further, the analysis produced two statistically significant interaction effects: of temporal relatedness and chronological distance, $F_1(2, 66) = 6.45$, $MSE = 3{,}512$; $F_2(2, 30) = 7.79$, $MSE = 1{,}180$; and of temporal relatedness and temporal orientation, $F_1(1, 33) = 14.51$, $MSE = 3{,}492$; $F_2(1, 15) = 8.81$, $MSE = 2{,}607$. The three-way interaction was not significant by participants, $F_1(2, 66) = 3.07$, $MSE = 2{,}178$, $p > .1$; nor by items ($F_2 < 1$).

In a second step, a 2 (temporal orientation) × 3 (chronological distance) ANOVA was performed on the related items. There was a significant main effect of temporal orientation, both by participants, $F_1(1, 33) = 7.35$, $MSE = 9{,}659$; and by items, $F_2(1, 15) = 8.37$, $MSE = 2{,}783$; with longer RTs for chronological items. In addition, there was a significant main effect of chronological distance, both by participants, $F_1(2, 66) = 13.69$, $MSE = 5{,}710$; and by items, $F_2(2, 30) = 14.16$, $MSE = 1{,}477$; with shorter RTs for more distant events. The two-way interaction was significant by participants, $F_1(2, 66) = 4.23$, $MSE = 2{,}505$; but not by items, $F_2(2, 30) = 1.10$, $MSE = 2{,}391$, $p = .35$.

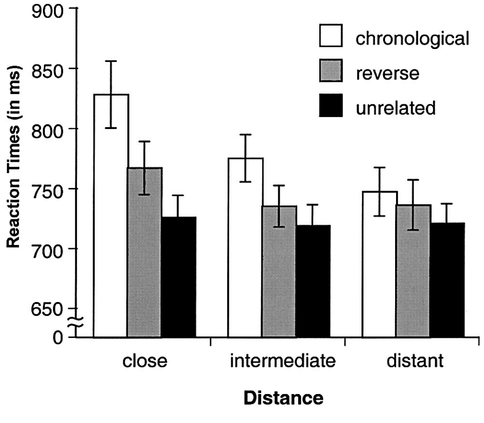

Figure 3. Temporal orientation—reaction times (in milliseconds) required to reject false probes depending on temporal orientation and chronological distance for Experiment 3. Standard error bars are included.

The results of Experiment 3 paralleled those of Experiment 2, using another item pool, in demonstrating that temporal relatedness between sentences and false probes increased RTs compared with unrelated items. In addition, the outstanding role of chronological probes found in Experiment 1 and 2 was supported. Of particular interest is the effect of chronological distance on RTs of false probes, with shorter RTs for more distant events. These data closely match the strong iconicity approach. In addition, the significant interaction of temporal orientation and chronological distance by participants pointed to the fact that the future-oriented effect of temporal information depended on the chronological distance of sentence and probe events. An increase in chronological distance reduced the preferred access of chronologically related events compared with reversely related events. A final concern with the two-way interaction effect from Experiment 3 was that the result was not as unambiguous in the item analysis as it was in the participant analysis. This may have been due to a lower power in the item analysis caused by the relatively small number of items.

General Discussion

Across two different paradigms and two different sets of content materials, the present study demonstrated the influence of temporal order information in general event knowledge on language comprehension. The General Discussion focuses on three main themes. First, we discuss what the results suggest about the issue of temporal orientation in script-based situation models. Second, the issue of temporal order relations in language comprehension is discussed with regard to research on inference generation. In this context, the question of whether temporal order relations are inferred online or offline will also be tackled. Third, the influence of chronological distance between everyday events in script-based situation model construction is discussed.

Temporal Orientation in Script-Based Situation Models

In all three experiments, a preferred temporal orientation of event sequences toward future time was found supporting the theoretical view of Freyd (1987). Different explanations can be given for this effect of temporal orientation. In Experiment 1, chronological targets were accessed faster than reverse targets. The temporal connectives *before* and *after* could not influence this result because they were considered to be of identical semantic complexity (Brent, 1989). In addition, the temporal relatedness for chronological and reverse items was controlled and very strong. Thus, the associations among the elements that compose the studied scripts could not be assumed to be unidirectional (cf. Kintsch, 1998). Because an SOA of 1,000 ms helped in speeding up and improving the recognition of temporally related items compared with an SOA of 200 ms, the preferred access to chronological items compared with reverse items could not exclusively be due to automatic spreading activation mechanisms. With Till et al.'s (1988) study it is argued that SOA intervals of 200–300 ms stand for automatic activation, whereas longer SOA intervals, for example of 1,000 ms, stand for controlled, elaborated processing. Monsell (1996) assumed that the activation levels of mental representations can be selectively changed by executive processes. This means that the focus of attention can be directed on the successor of an event in semantic memory. Then, the successor is in a higher state of activation and can be quicker accessed and retrieved. Another explanation is that stored knowledge structures (e.g., scripts) guide comprehension in a top-down fashion. Experiments 2 and 3 supported this view: If readers did not access event knowledge in sentence–probe recognition tasks, there should have been no costs associated with processing related false probes compared with unrelated false probes. However, these costs were found.

Inference Accounts of Processing Temporal Order Relations

This view supports applying the body of research on inference generation in further considerations. The temporally reverse and chronologically oriented items correspond with past or concurrent and future event inferences, all of which belong to knowledge-based inferences (Millis, Morgan, & Graesser, 1990). There is considerable evidence that past or concurrent event inferences, which mostly map onto bridging inferences, are made online. The status of whether future event inferences (predictive or elaborative inferences) are generated during comprehension is unclear. According to Millis et al. (1990) readers do generate predictions about upcoming events in statements. However, there are also studies that indicate that readers do not make predictive inferences online (Keenan, Golding, Potts, Jennings, & Aman, 1990; Singer & Ferreira, 1983). McKoon and Ratcliff (1986) concluded that these inferences were drawn, although minimally. A minimal encoding might represent a few semantic features or a variety of possibilities. The highly predictable nature of events (that is, a preexisting relation between event concepts in semantic memory that is activated) or a context that is highly constrained by the passage content and world knowledge may cause participants to infer succeeding events (Magliano, Baggett, & Graesser, 1996; van den Broek, 1994). In the present study, one important source of constraints is the controlled and strong temporal relatedness of items. That is, when an initiating event was in focus it provided strong support not only for activating a particular preceding event but also for activating a particular succeeding event.

It is well-known that event sequences about which we have background knowledge typically have a causal relation of some sort. Trabasso, van den Broek, and Suh (1989) differentiated motivational, physical, psychological, and enabling relations. All causal relations have been considered to have four properties: temporal priority, operativity, necessity, and sufficiency in the circumstances. In the present study, the property of temporal priority was focused. Given the described constraints of the stimulus materials and the experimental tasks, the present results clearly show that readers spontaneously accessed and integrated first the successor (consequence) and then the predecessor (antecedent) of the focal sentence event.

This finding raised the question of whether the superiority effect of chronological events varies by SOA condition. Experiments 2 and 3 demonstrated that longer SOAs led to stronger influences of background knowledge on sentence processing. At the beginning, the meaning of the sentence was available. Next, only future-oriented events were activated. Later on, past-oriented events were also accessed. It is interesting to note that similar results were observed in studies in which persons at different levels of expertise recalled medical case records and diagnoses (Groen & Patel, 1988; Schmidt & Boshuizen, 1993). Interns behaved like participants who mostly depended on the sentence meaning in the short SOA conditions. Medical experts behaved like participants who had a rich situation model in the long SOA condition.

What do these results tell us about when people infer temporal order information? There are two ways in which this could happen. First, the inference is drawn online, that is, while reading the sentence (including the SOA interval), and then the access of the probe is primed. Second, the inference is drawn offline, that is, while checking the probe against the sentence. This context-checking procedure (Forster, 1981) is considered to compare the meaning of the probe word with the meaning of the constructed situation model that is still in working memory. If this was true, the variation of SOA should affect RTs for chronological and reverse items in the same way, because both item groups were controlled for temporal order relatedness, typicality, semantic relatedness, and so forth (cf. Experiment 1). Therefore, the good fit between context and probe word should not differ. The data, however, did not support this claim. Therefore, temporal order information may have been inferred online. This outcome supports the view of Millis et al. (1990) and McKoon and Ratcliff (1986) that predictive inferences can be drawn. In addition, it points to the fact that the activation of succeeding events appears to be greater than that of preceding events when the events are highly predictable.

Influence of Chronological Distance on Script-Based Situational Models

A third main theme was whether the chronological distance between events affected script-based situation model construction. In the introduction, predictions were made by referring to two contrasting models. The results clearly support the strong iconicity account (cf. Zwaan, 1996). If readers construct a situational representation, then the degree of preactivation for the critical events by the previous events appears to be a function of chronological distance. Findings such as these led Zwaan (1996) to propose that in the situation model constructed in the close condition, these events should be closely linked, whereas the links should be weaker in the intermediate and far conditions. The stronger the links between the two events, the faster the access from the first to the second event should be.

Extending this explanation into the area of the present experiments, we assumed the events and their links to be part of the preexperimental background knowledge that is integrated into the script-based situation model. Kintsch and Mannes (1987) argued that scripts consist of an ordered list of scriptural episodes, each of which revolves around a goal and its outcome. Taking into account that events have multiple antecedents and outcomes, we assumed the knowledge structure to resemble a network rather than a chain with relations between events varying in strength (cf. van den

Broek, 1994). In the case of routine events, however, we assumed a preferred path (a chain of events) that has been frequently used in the past. When activation spreads through this network, it allows for a faster access to close events compared with distant events. Therefore, close events can be faster and more strongly integrated into the situational model than more distant events. This specific view clearly predicts that temporally related probe events that had not occurred in the sentence but were integrated into the situation model should cause a momentary increase in online processing load because of interferences between the sentence representation and the situational model. Therefore, close false probe events may lead to longer RTs than distant false probe events, because stronger situation model integration needs to be overridden by sentence representation. The present results are not consistent with the scenario view that temporal intervals within the boundaries of a scenario or script can be integrated with identical difficulty (Anderson et al., 1983).

Conclusion

The present experiments demonstrate the influence of temporal orientation and chronological distance in event knowledge on sentence comprehension. According to Radvansky et al. (1998), events can be integrated in memory on the basis of temporally contiguous information as indicated by temporal markers or by direct experience. The present study clearly demonstrates a superiority effect for future-oriented events indicating that it is a robust phenomenon that occurs for a range of tasks and materials. In addition, it points to the fact that the internal temporal dimension appeared to reflect the chronological distance of everyday events. Of course, the experimental stimuli provided only a rudimentary skeleton for constructing situation models. In addition, time is only one of several tools for organizing such models (Radvansky et al., 1998). However, even with the relatively less naturalistic and less complex situation of the present experiments, the influence of temporal information in semantic memory was still observed. Whether and how background knowledge interacts with other temporal expressions, such as temporal adverbials, tense, and aspect, to affect the construction of situation models remains an issue for future research.

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