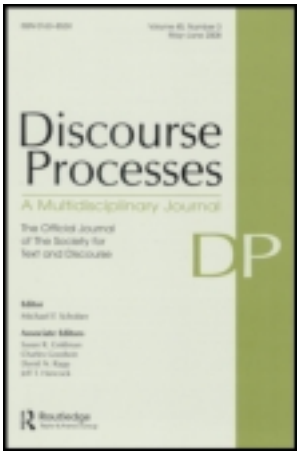

Discourse Processes
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/hdsp20

Propositional Integration and World-Knowledge Inference: Processes in Understanding *Because* Sentences

Reinier Cozijn [a], Leo G. M. Noordman [a b] & Wietske Vonk [c d]

[a] Tilburg School of Humanities, Tilburg University, Netherlands

[b] Donders Institute for Brain, Cognition, and Behavior, Radboud University, Nijmegen, Netherlands

[c] Max Planck Institute for Psycholinguistics, Nijmegen, Netherlands

[d] Center for Language Studies, Radboud University, Nijmegen, Netherlands

Available online: 26 Jul 2011

To cite this article: Reinier Cozijn, Leo G. M. Noordman & Wietske Vonk (2011): Propositional Integration and World-Knowledge Inference: Processes in Understanding *Because* Sentences, Discourse Processes, 48:7, 475-500

To link to this article: http://dx.doi.org/10.1080/0163853X.2011.594421

Discourse Processes, 48:475–500, 2011

ISSN: 0163-853X print/1532-6950 online
DOI: 10.1080/0163853X.2011.594421

Routledge
Taylor & Francis Group

Propositional Integration and World-Knowledge Inference: Processes in Understanding *Because* Sentences

Reinier Cozijn
Tilburg School of Humanities
Tilburg University, Netherlands

Leo G. M. Noordman
Tilburg School of Humanities
Tilburg University, Netherlands
Donders Institute for Brain, Cognition, and Behavior
Radboud University Nijmegen, Netherlands

Wietske Vonk
Max Planck Institute for Psycholinguistics, Nijmegen, Netherlands
Center for Language Studies Radboud University Nijmegen, Netherlands

The issue addressed in this study is whether propositional integration and world-knowledge inference can be distinguished as separate processes during the comprehension of Dutch *omdat* (*because*) sentences. "Propositional integration" refers to the process by which the reader establishes the type of relation between two clauses or sentences. "World-knowledge inference" refers to the process of deriving the general causal relation and checking it against the reader's world knowledge. An eye-tracking experiment showed that the presence of the conjunction speeds up the processing of the words immediately following the conjunction, and slows down the processing of the sentence final words in comparison to the absence of the conjunction. A second, subject-paced reading experiment replicated the reading time findings, and the results of a verification task confirmed that the effect at the end of the sentence was due to inferential processing. The findings evidence integrative processing and inferential processing, respectively.

Correspondence concerning this article should be addressed to Reinier Cozijn, Tilburg School of Humanities, Tilburg University, P.O. Box 90153, 5000 LE Tilburg, The Netherlands. E-mail: r.cozijn@uvt.nl

The central question in this study is whether propositional integration and world-knowledge inference are two separate processes during the comprehension of *because* sentences. An example of such a *because* sentence is (1), adapted from Crothers (1979):

(1) History is not a science because in history particular facts are more important than causal laws.

The conjunction *because* segments the sentence into a main and a subordinate clause. On the basis of the meaning of *because*, one understands that the two clauses express a consequence and a cause, and that they can be integrated in a causal link: The relation between "history not being a science" and "facts being more important than causal laws" is a causal relation. By "propositional integration" in these *because* sentences, we refer to the process by which the comprehender establishes the type of relation—in this case, a causal relation that exists between the two propositions expressed by the two clauses. However, understanding can go beyond simply establishing that there is a causal relation. Listeners and readers can achieve a deeper understanding of the causal relation by making a world-knowledge inference that underlies the *because* sentence. The inference in this example can be characterized as follows: A sentence "p because q" implies that there exists a generalized, causal relation "if q then p." In this example, the inference is as follows: If in a discipline particular facts are more important than causal laws, then that discipline is not a science; or, by *modus tollens*: In science, particular facts are not more important than causal laws. And, assuming that in the context of a science discussion causal laws and particular facts are not equally important, the inference is as follows: In science, causal laws are more important than particular facts. This inference is the major premise in a syllogism. Making the inference amounts to deriving this premise and matching it to the comprehender's world knowledge. This can be accomplished in at least two ways, depending on the comprehender's knowledge. If comprehenders already have knowledge about science, fact, laws, and the relations among these concepts, this knowledge will be activated, and the inference will be checked against it. In this case, the inference will be accepted as a true statement: The causal relation is justified with regard to world knowledge. If comprehenders lack this knowledge, they will understand that the speaker or writer suggests to draw the inference; and they will conclude that, apparently, in science, causal laws are more important than facts. In this case, the inferred information is added to their knowledge base. The process of checking or adding knowledge is called a world-knowledge inference.

The difference between integration and inference and the representations resulting from them can further be clarified by comparing sentence (2) with sentence (1):

(2) History is not a science although in history particular facts are more important than causal laws.

If understanding only consists of the integration process, the comprehender understands almost the same information in understanding sentence (2) as in understanding sentence (1). The two propositions ("History is not a science," and "In history, particular facts are more important than causal laws"), and the fact that there is a relation between the propositions, are the same in both sentences; only the type of relation in (1) and (2) differs. The relation in (2) is a concessive relation. The inference process, therefore, should lead to an underlying proposition opposite to the one in sentence (1). The underlying (false) proposition in (2) is that, in science, particular facts are more important than causal laws. For a deep and appropriate understanding of sentence (2), the underlying proposition is matched against world knowledge and appears, then, to be false. Therefore, the propositional integration process in the sentence requires the construction of a relation internal to the representation, and the inference process requires a relation with a model of the world. We come back to this distinction in the General Discussion.

There is some experimental evidence that the integration process and the inference process in understanding *because* sentences can indeed be differentiated; although, at the time, the results of these experiments were not interpreted in this way. Consider, for example, an experiment of Noordman, Vonk, and Kempff (1992), who used expository texts consisting of 6 to 10 complex sentences on not well-known topics[1] (e.g., propellants in spray cans) that contained *because* sentences as in (3):

(3) Chlorine compounds make good propellants because they react with almost no other substances.

The inference triggered by this sentence is that propellants must not react with the material in the spray can. If readers make the inference while reading sentence (3), Noordman et al. (1992) predicted the reading time for the *because* clause in (3) to be shorter when the preceding text contained a sentence that expresses the information that has to be inferred, as in (4), than when the preceding text did not contain this sentence:

(4) Propellants must not combine with the product in the spray can.

[1]In a questionnaire after the reading experiment, it was verified that the topics were not well-known.

After reading the text, readers had to verify statements with respect to the text, one of which being an inference verification statement. Noordman et al. (1992) predicted that if the inference is made during reading the *because* clause, the inference verification statement requires the same verification time whether sentence (4) was present or not in the text.

The results were just the opposite. The reading time for sentence (3) when sentence (4) was present earlier in the text did not differ from the reading time for that sentence when sentence (4) was absent, and the verification time for the inference was shorter when sentence (4) was present than when it was absent. The results indicated that readers did not make the inference online, but made the inference later when requested in the verification task. Therefore, readers must have stored in their discourse representation that there was a causal relation between the clauses; otherwise, they would have been unable to verify the causal relation. Thus, the results showed that the integration process must have taken place during reading, but the inference process did not.

The experimental results were unexpected, but it is important to note what the task and the materials were in this experiment: Participants read expository texts on unfamiliar topics, and they just had to read in their normal way—that is, without a specific reading task. That a reading task affects inference-making was clear from results of two additional experiments (Noordman et al., 1992). In one experiment, participants read the same texts, but were instructed to read them so as to be able to detect inconsistencies. In this case, a difference in reading times for sentence (3) was found between the two conditions and no difference in verification times for the verification statement. This pattern of results indicated that the inferences were made online. In a second experiment, without a verification task, participants received a particular reading goal formulated as a question before reading, such as "How do spray cans work?" Again, a reading time difference for sentence (3) in the two conditions was obtained, indicating that the inferences were made online.

In another study (Noordman & Vonk, 1992; Simons, 1993), the instructions were simply to read, but the knowledge of the readers was varied. Experts in economics and non-experts read economic texts with *because* sentences. The economic concepts were familiar to both the experts and the non-experts; the relations between the concepts, however, were familiar only to the experts. Evidence for online inferences was obtained for the experts. The non-experts did not make the inferences online, but they were able to verify the causal relation after reading the text. Therefore, the non-experts must have stored a causal relation between the propositions. The results for the non-experts again give evidence for the distinction between integration and inference.

The results can be interpreted in terms of different representations readers construct in understanding these sentences. In the Noordman et al. (1992) experiments, the readers in the normal reading task were supposed to have integrated

the two clauses. The representation that the readers construct of a sentence, such as (3), then consists of the following text propositions (Fletcher & Chrysler, 1990; Kintsch, 1998):

1. Chlorine compounds make good propellants.
2. Chlorine compounds react with almost no other substances.
3. Because (2, 1).

However, readers in the more demanding task, as well as readers who are experts (Noordman & Vonk, 1992), made the inferences during reading, whereas the other readers did not make the inference during reading. For readers in the more demanding task, this meant that they added the inferred proposition as new information; for readers who were experts, this meant that they checked the inferred proposition against their knowledge base. For these two groups of readers, the representation of the sentence contains, apart from Propositions 1, 2, and 3, an additional knowledge proposition: Propellants should not react with other substances.

The Noordman et al. (1992) and Noordman and Vonk (1992) experiments offered some evidence for the differentiation between integration and inference processes. However, propositional integration and world-knowledge inference could not be identified as separate processes *during* the comprehension of the sentences on the basis of the sentence reading times.

Millis and Just (1994) collected data *during* reading in a study that investigated the role of *because* in understanding causal clauses. It should be noted, however, that they did not make the distinction between propositional integration and world-knowledge inference. They used the term *integration* as a superordinate category, comprising inferences. In the sentences they presented, the conjunction was either present or not. Among the data they collected were probe recognition times to the verb from the first clause, reading times of the second clause, answering times, and answering accuracy for comprehension questions posed after the sentence had been read. The presence of *because* decreased the probe recognition times at the end of the second clause. In addition, the accuracy to the comprehension questions was greater, and the answering times for these questions shorter, when the conjunction *because* was present than when it was absent. The conjunction decreased the reading time of the second clause, except the reading time for the last word in the clause, which showed an increase in reading time. The quicker reading in case the conjunction was present indicates, according to Millis and Just, that readers waited until the end of the sentence to integrate the clauses. They interpreted their results as supporting what they proposed as the "delayed reactivation hypothesis": "A connective reactivates the content of the first clause when the end of the sentence is processed, and not when the second statement is first encountered" (p. 144).

This delayed reactivation hypothesis is supported by the reading time results in only one of their experiments.

The study by Millis and Just (1994) raises the question of what kind of process they exactly investigated. They did not investigate whether inferences were made: The questions that were asked concerned the first clause or the second clause, and not the relation between the clauses. Consequently, no test of inferences was involved. In continuation of the Millis and Just study, Millis, Golding, and Barker (1995), using lexical decision times for inference words, did obtain evidence for inference processes. However, they did not differentiate between integration and inference. With respect to integration, Millis and Just assumed that it takes place at the end of the sentence because "integration requires both clauses to be simultaneously active in working memory" (p. 144). However, in our conception of integration, it can occur as soon as the reader processes the conjunction.

Another question raised by Millis and Just's (1994) study is how robust their reading time data are. In the first experiment, a decrease in reading time of the second clause—except the last word—and an increase in reading time for the last word were found. For Experiment 2, no reading time data are reported; in Experiment 3, the reading time for the last word was not longer, but shorter, when the conjunction was present (for the most plausible sentences); and. in Experiment 4, the effects on the reading times were not significant by conventional standards. In addition, Mouchon, Ehrlich, and Loridant (1999) did not replicate the decrease in reading time for the middle segment and the increase for the last segment of the second clause as obtained in Experiment 1 by Millis and Just. A limitation of both studies is that isolated sentences were used and that participants had to perform quite a few tasks that may have been confusing, and may have led to results that are difficult to interpret. Moreover, in some conditions of the experiments by Millis and Just, the causality of the relations was far-fetched. We want to substantiate the findings of Millis and Just's first experiment with a more natural reading task using target sentences embedded in texts.

The aim of our experiments is to collect further experimental evidence for the differentiation between a propositional integration process and a world-knowledge inference process during sentence processing. To investigate online inferential processing, texts were used that contained a causal relation that was expressed either as a main clause and a subordinate clause connected by the conjunction *because* (in Dutch, *omdat*, which, like *because*, indicates a subordinate causal clause) or as two main clauses without a conjunction. Familiar causal relations were used because, as indicated earlier, it has been shown that familiarity is a prerequisite for making the causal inference online. A second prerequisite for this kind of inference is the presence of the conjunction (Cozijn, 1992; Singer & O'Connell, 2003). Therefore, the presence of the conjunction was manipulated.

To gain insight in the integration and inference processes during sentence processing, the reading times were measured not for entire clauses, but for parts of the clauses, as indicated in the Method section. It was expected that the presence of the conjunction has two effects on the processing of the causal relation. First, the conjunction facilitates the integration process. Readers understand consecutive sentences not as separate sentences, but try to integrate them according to, for example, the "nextness" principle by Ochs (1979) and the principle of continuity ("Readers assume, by default, that continuity is maintained") by Segal, Duchan, and Scott (1991, p. 32), and there is abundant empirical evidence since Kintsch and Van Dijk (1978) that readers relate consecutive sentences. The propositional integration process can start as soon as the second clause is presented. If the first word of the second clause is a conjunction, integration is facilitated. Therefore, the reading times of the words in the sentence after the conjunction should be shorter when the conjunction is present than when it is absent. Second, the conjunction elicits the inference that justifies the causal relation. This inference process can start as soon as sufficient information about the causal relation in the second clause has become available. Therefore, the reading times later in the second clause should be longer when the conjunction is present than when it is absent.

The first experiment used the eye-movement registration technique to obtain, unobtrusively, a temporally fine-grained picture of the reading times of the causal sentences. The second experiment used a self-paced reading method to measure the reading times on the same texts; and, more important, exploited a verification task by which the reading time results later in the second clause can be interpreted in terms of inferential processing.

EXPERIMENT 1

In Experiment 1, the reading times were measured on short narrative texts that contained a causal relation. The stories dealt with everyday situations, and the causal relations in the stories were familiar to the readers. Each story was followed by a verification statement that served to encourage careful reading.

Method

Participants. Forty-two students of Nijmegen University (all with normal, uncorrected vision) were paid to participate (28 women and 14 men, ranging in age from 20–27). Of these participants, 40 were entered into the analysis. The data of 2 participants were excluded from further analysis because of poor data quality.

Materials. Thirty texts were written about everyday topics. Each text consisted of seven (complex) sentences: four introductory sentences, one target sentence, and two closing sentences. The target sentence consisted of a consequence in the first clause and a cause in the second clause. In one condition, the clauses were connected by the conjunction *because*; in this condition, the target sentence consisted of a main clause and a subordinate clause. In the other condition, there was a full stop between the clauses. An example of a target sentence is as follows: "On his way to work he experienced a long delay, because there was a large traffic jam on the highway." This sentence expresses the conclusion (he was delayed) and the minor premise (he was in a traffic jam) of a syllogism. The major premise of the syllogism is the information that can be inferred: A traffic jam leads to a delay. Table 1 presents an example of an experimental text with the target sentence in the two conditions: conjunction present and conjunction absent.

Two preliminary materials studies, one sentence completion study and one plausibility judgment study, were conducted to select 24 texts for the experiment. The aim of these preliminary studies was to obtain texts with sentences that expressed plausible causal relations that are part of general world knowledge. In the sentence completion study, 49 participants read the text up to and including

TABLE 1
Example of an Experimental Text (and the Literal English Translation) in Experiment 1

	De heer Smit verliet rond half acht het huis. Hij moest op zijn werk een belangrijke vergadering voorzitten. Daarom was hij van plan om van tevoren de papieren goed door te nemen. Hij haalde zijn auto uit de garage en reed weg. *Hij ondervond een flinke*
A	[*vertraging, omdat* |[1]*er* |[2]*een lange file was ontstaan* |[3]*op de snelweg.*| Hij] /
B	[*vertraging.* |[1]*Er* |[2]*was een lange file ontstaan* |[3]*op de snelweg.*| Hij]
	was blij dat hij wat eerder was vertrokken. Hij hield er niet van om te laat te komen.
	Mister Smith left at about seven thirty the house. He had, at work, to chair an important board meeting. That is why he had planned to study the papers thoroughly in advance. He fetched his car from the garage and drove off. *He experienced a long*
A	[*delay, because* |[1]*there* |[2]*was a large traffic jam* |[3]*on the highway.*| He] /
B	[*delay.* |[1]*There* |[2]*was a large traffic jam* |[3]*on the highway.*| He]
	was glad that he had left a bit earlier. He did not like to be late.

Note. Causal relation sentences (in italics) are presented in two conditions: with the causal conjunction *because* (A) and without the causal conjunction *because* (B). Numbered (superscripted) vertical bars precede the three regions of interest.

the conjunction *because*, and completed the last sentence with what they believed to be the most plausible cause for the event described in the first clause. For 18 texts, the causes produced by 70% or more of the participants corresponded to the cause in the originally written texts. For the other texts, slight changes were made so as to make the original cause more plausible in the text. In the second materials study, 26 participants judged the plausibility of the causes of the 30 texts. Twenty-four texts were selected[2] that had a mean plausibility score higher than 3.5 on a 4-point scale. The overall average plausibility score was 3.90 ($SD = 0.016$).

The clauses expressing the causes in the causal relation sentences were divided into three regions (see Table 1). The logic of dividing the causal clause into three regions was as follows: Region 1 consisted of the first word after the conjunction; or, in the condition where the conjunction was absent, of the first word of the second clause. This region was not of particular interest to the causal processing of the sentence, but should show the effect of sentence initial processing (Haberlandt, 1984; cf. Vasishth, 2003), and was, therefore, separated from Region 2. Region 2 represented the middle part of the second clause. This part of the clause was central to the meaning of the second clause. It expressed the cause of the causal relation. This region was rather large because, in Dutch, the word order in the condition with the conjunction differs from the word order in the condition without the conjunction. For instance, the word order in the middle region of the sentence in Table 1, which reads "[omdat er] een lange file was ontstaan" if the conjunction is present, changes into "[Er] was een lange file ontstaan" if the conjunction is absent. Region 2, therefore, always contained the same words, but in a different order. Region 3 concluded the second clause with a prepositional phrase that was not central to the meaning of the clause.

In addition to the 24 experimental texts, 24 filler texts were included. These texts resembled the experimental texts in topics and style, but contained conjunctions other than *because*: *although, but, while, after, when*, and *for.* Furthermore, the filler texts varied in the number of sentences, from 6 to 11.

Finally, for each text, a verification statement was generated. For the experimental texts, the statements contained the information that could be inferred from the causal relation sentence, and were always true. For instance, the verification statement for the example text in Table 1 read, "A traffic jam leads to a delay." The verification statements for the filler texts were always false.

Design. A list was created in which the experimental texts and the filler texts were distributed semi-randomly. The two experimental conditions, conjunction present or absent, were distributed semi-randomly over the 24 experimental texts within the list, resulting in 12 experimental items with the conjunction and

[2]The materials are available from Reinier Cozijn.

12 experimental items without the conjunction. Since each text was presented to a participant in only one of the two conditions, a second list was created in which the conditions were mirrored. A text that contained the conjunction in List 1 did not contain the conjunction in List 2, and vice versa. Participants were randomly assigned to a list.

Apparatus. The stimuli were presented at a refresh rate of 72 Hz on a 19 in. monitor. The experiment was carried out on two personal computers, one for stimulus presentation and one for data recording. Horizontal and vertical eye movements of the right eye of the participant were sampled at a rate of 200 Hz by an Amtech ET3 infrared pupil reflectance eye tracker (Katz, Müller, & Helmle, 1987). The eye tracker has a spatial resolution of 5 to 10 min of arc—that is, approximately 0.25° of visual angle.

Participants were restricted in their head movements by the use of a chin rest, a forehead rest, and a bite bar (with dental impression compound). The distance between the participant's eye and the monitor screen was 59 cm. At this distance, the display area used for text presentation subtended 22° of visual angle horizontally and 12° vertically. The texts were presented in graphics mode (800 × 600) in a black, non-proportional font (Courier New, 12 pt.) and double-spaced on a light grey background. Each character subtended approximately 0.28° of visual angle.

Procedure

The experiment consisted of two blocks of 24 items. Each block was preceded and followed by a 12-point calibration routine. Between the blocks, there was a break, allowing the participant to take a rest.

Participants were instructed to read the texts thoroughly, but quickly, in order to understand them. After each text, they had to verify a statement about the text. They were told that they should not make errors, and could take as long as they needed to verify the statement. The experiment started with three practice items. Each item consisted of an asterisk, followed by a text and a verification sentence. The asterisk remained on the screen until the participant was ready to start reading the next text. At the press of a button, the text started at exactly the same position as the asterisk. When the text had been read, the button had to be pressed. The text disappeared, and a statement was presented for verification. After verification, a 4-point recalibration routine was run, and the asterisk for the next item appeared on the screen, indicating that the procedure started anew.

The layout of the texts was left-aligned. Because the measurements of fixation times at the beginning and the end of a line of text are blurred due to making a return sweep, the regions of interest—that is, the middle and the final regions of the clauses expressing the causes (Regions 2 and 3)—were presented on one

line, but not at the beginning or the end of a line. The total duration of the experiment was 1 hr.

Results

From the eye-movement data, two first-pass measures were calculated: *forward reading time* (Vonk & Cozijn, 2003) and *go-past reading time* (W. S. Murray, 2000). The main interest in this study lies in first-pass reading processes, where first-pass reading is defined as the time spent on a region from the moment it is visited for the first time, and has not been skipped earlier. This assures the capturing of early and immediate reading processes. Forward reading time is defined as the time spent on a region until it is left in a forward direction. Go-past reading time is defined as the time spent on a region until the region is left in a forward direction, including the time spent on all regressions to earlier parts of the text. The calculation of these measures is performed by aggregating the durations of the fixations on a region, including the durations of the intermittent saccades. The decision to include saccade durations in the computation of aggregated measures is justified because language processing continues during saccades (Irwin, 1998; Vonk & Cozijn, 2003).

The forward reading time is a measure of ongoing reading. This measure is prone to suffer from lack of observations because it does not include cases where the reader has decided to jump back in the text. The go-past reading time takes these cases of regression into account. This results in more observations in the go-past reading times than in the forward reading times, but also in a greater variance and, therefore, reduced power of the statistical test. The two measures capture different reading strategies when a reader encounters a difficulty in the text. The forward reading time mainly captures sustained processing behavior, whereas the go-past reading time mainly captures rereading behavior.

From the eye-movement data for the target sentences, saccades and fixations were calculated. Saccades were determined using a velocity threshold algorithm with a starting threshold of 0.30° per second and an ending velocity of 0.10° per second. The minimum saccade amplitude was set to 0.20°. Eye movements with an amplitude below this value were not considered to be saccades. Fixations were defined as the intervals between saccades. The calibration data, as well as the resulting saccades and fixations, were checked for errors and anomalies. The fixations were automatically assigned to the words in the text by the program *Fixation* (Cozijn, 2006).

For each region of interest, analyses of variance (ANOVAs) were carried out on the reading times with participants as a random variable ($F1$) and with items as a random variable ($F2$). The $F1$ analysis contained *conjunction* (with the levels present and absent) as a within-subjects factor and *participants group* (with 2 levels) as a between-subject factor. The $F2$ analysis contained *conjunction* as a

within-subjects factor and *items group* (with 2 levels) as a between-subject factor. Where applicable, confidence intervals (CIs) around contrasts were computed according to Bird (2002). Reading times belonging to items on which the participants had made a verification error (5.7% of the data; 4.8% and 6.7% in the conditions with and without conjunction, respectively), as well as outliers based on participants and item means (on 2.0 *SD*s), were excluded from the analyses. Apart from these excluded observations, there were some missing data as a result of skipping or blinks. Because all regions were separately analyzed for each of the two dependent measures, the percentages of valid observations are reported per region.

Forward reading times. The mean forward reading times, ANOVAs, 95% CIs, and the percentages of valid observations are shown in Table 2. There were only a few observations in Region 1, and there were no effects. Region 2, the middle region of the second clause, revealed an effect of *conjunction.* The region was read faster if the conjunction was present than if it was absent. In Region 3, the final part of the second clause, the presence of the conjunction had an effect in the $F1$ and a marginal effect in the $F2$. The results indicated that, contrary to Region 2, the region was processed more slowly if the conjunction had been present than if it had been absent. ANOVAs were carried out for Regions 2 and 3 combined. These regions formed two levels of a new factor, *region.* The analyses revealed a significant interaction of *region* with *conjunction*: $F1(1, 38) = 13.95$,

TABLE 2
Mean Forward Reading Times (in Milliseconds), Their Analyses of Variance, and 95% Confidence Intervals around Contrasts as a Function of Conjunction (Present or Absent) for Regions 1, 2, and 3 in Experiment 1

	Region		
Conjunction	*1*	*2*	*3*
Present	214 (31)	589 (184)	427 (98)
Absent	235 (61)	666 (159)	389 (93)
Percentage of observations	22.4	78.1	75.8
$F1$ (*df*; F)	1, 26; 2.03	1, 38; 9.12*	1, 38; 11.83*
$F2$ (*df*; F)	1, 16; 2.42	1, 22; 13.67*	1, 22; 3.64#
Min F' (*df*; F)	1, 41; 1.10	1, 59; 5.47*	1, 35; 2.78
d (in milliseconds)	21	77	38
95% confidence interval	−3.68, 46.31	25.54, 128.69	15.73, 60.51

Note. Standard deviations are in parentheses. Percentages of observations per region are shown below the means.

*$p < .05$. #$p = .070$.

$p < .05$; $F2(1, 22) = 10.55$, $p < .05$; Min $F'(1, 50) = 6.01$, $p < .05$, attesting to the opposite effects of *conjunction* in the two regions.

Go-past reading times. The mean go-past reading times, the ANOVAs, 95% CIs, the percentages of observations, and the percentages of regressions are shown in Table 3.

In Region 1, there again were only a few observations. However, in contrast to the analyses of the forward reading times, the conjunction had a significant effect: The region was read faster if the conjunction was present than if it was absent. A similar effect was found in Region 2: The region was read significantly faster if the conjunction was present than if it was absent. In Region 3, the effect of *conjunction* was significant as well: Reading times were longer if the conjunction was present than if it was absent. Finally, the combined analyses of Regions 2 and 3 showed a significant interaction between *region* and *conjunction*: $F1(1, 38) = 28.75$, $p < .05$; $F2(1, 22) = 17.63$, $p < .05$; Min $F'(1, 47) = 10.93$, $p < .05$.

TABLE 3
Mean Go-Past Reading Times (in Milliseconds), Their Analyses of Variance, and 95% Confidence Intervals around Contrasts and Percentages of Regressions for Regions 1, 2, and 3 as a Function of Conjunction (Present or Absent) in Experiment 1

	Region		
Conjunction	*1*	*2*	*3*
Present	263 (74)	649 (221)	512 (134)
Absent	338 (123)	749 (192)	448 (132)
Percentage of observations	31.4	91.1	89.8
$F1$ (df; F)	1, 34; 10.36*	1, 38; 14.83*	1, 38; 14.62*
$F2$ (df; F)	1, 21; 15.54*	1, 22; 14.70*	1, 22; 6.82*
Min F' (df; F)	1, 54; 6.22*	1, 55; 7.38*	1, 22; 4.65*
d (in milliseconds)	75	100	64
95% confidence interval	26.35, 123.65	47.26, 152.47	30.58, 97.42
Percentage of regressions (conjunction present)	8.3	13.8	18.8
Percentage of regressions (conjunction absent)	12.5	15.4	13.5

Note. Standard deviations are in parentheses. Percentages of observations per region are shown below their respective means.

*$p < .05$.

Regressions. Regressions occurred relatively often. For Regions 2 and 3, the percentages of regressions were 14.6% and 16.2%, respectively. If one takes a closer look at the regressions, it seems that they were not equally distributed over the conditions in this experiment. In Table 3, it can be seen that for Regions 1 and 2, most regressions occurred in the condition where the conjunction was absent. The regressions in Region 3 showed a reverse pattern: There were more regressions if the conjunction was present. These patterns are in line with the notion that regressions may reflect deeper processing. However, statistically, no clear effects of *conjunction* emerged: in Region 1, $F1(1, 44) < 1$ and $F2(1, 38) = 3.348$, $p = .075$; in Region 2, $F1(1, 50) < 1$ and $F2(1, 30) < 1$; in Region 3, $F1(1, 60) = 8.953$, $p < .01$ and $F2(1, 42) = 2.270$, $p = .139$.

Discussion

The results of Experiment 1 showed that the reading times of the middle part of the causal clause that contained the causal information were shorter, and the reading times of the final part of the sentence were longer if the conjunction was present than if it was absent. These results were obtained in the analyses of the forward reading times, as well as in those of the go-past reading times, indicating that the influence of the conjunction is unrelated to the processing strategy of the readers.

The results are in line with the reading times of the first experiment of Millis and Just (1994). However, in the present study, participants read the texts in a more natural way. The eye-movement registration technique ascertained accurate, but also unobtrusive, measurements of reading times; and the target sentences were not presented in isolation, but were embedded in short narratives. Readers were, thus, naive with respect to the status of the sentences in the experiment. Therefore, it can be concluded that the reading times in this study are an accurate reflection of the time readers take to process the sentences.

The main question is how the reading pattern may be explained. As mentioned earlier, Millis and Just (1994) attributed the decrease in reading time to a delay in processing, and the increase to the reactivation of the first clause and its integration with the second clause into the overall sentence representation. In our view, there is no reason to delay the processing of the second clause until the end of the sentence is reached. On the contrary, the causal conjunction indicates how the second clause should be integrated with the first, and this information helps the reader in integrating the words in the second clause into the sentence representation. The conjunction speeds up processing the beginning of the subordinate clause. However, when reaching the end of the sentence, the reader is slowed down by the conjunction: Readers have to make the inference—that is, they have to justify the causal relation against their world knowledge.

The presence versus absence of the conjunction is confounded with word order and sentence structure. In Dutch, the word order of the second clause—when the conjunction is present—differs from the word order in the second sentence—when the conjunction is absent. The question is whether word order might have accounted for the results. A study reported by Koornneef (2008) suggests that this is not the case. Koornneef conducted reading experiments with the Dutch causal conjunctions *omdat* and *want. Want* is like *omdat* a backward causal conjunction (i.e., it signals that the cause follows the consequence). However, unlike *omdat*, it is a coordinating conjunction, and the *want* clause has the same word order as a main clause. Koornneef investigated the influence of implicit causality information in interpersonal verbs on the processing of pronouns in sentences such as, *David bood Linda excuses aan omdat/want hij* ... 'David apologized to Linda because he ...', and measured the reading times after *omdat* and after *want* on the words following the pronoun in the second clause. The difference in word order did not have any influence on the effect of implicit causality he found on these words. Therefore, it is very unlikely that the difference in word order is responsible for the differences in reading times we found in our experiment.

The absence versus presence of the causal conjunction is also confounded with the difference between two main clauses versus a main clause and a subordinate clause. Several remarks should be made. First, it may be argued that information in a subordinate clause is regarded as less important than information in a main clause and, therefore, receives less attention during reading. However, no evidence is obtained for this position: The reading time for the second sentence did not differ from the reading time for the corresponding part of the subordinate clause (excluding the conjunction and, in both conditions, the first word). An additional ANOVA showed that neither the difference of 39 ms for the forward reading times was significant (95% CI = −10.51, 88.49), nor the difference of 37 ms for the go-past reading times (95% CI = −25.98, 100.59). Therefore, the syntactic difference between the main second sentence and the subordinate clause did not affect the reading time. Only the distribution of the reading times over the parts of the clauses in the two conditions differed.

Second, one may argue that, in the case of two main clauses, there are sentence wrap-up processes at the end of the first sentence and that, therefore, the wrap-up processes at the end of the second sentence are shorter than for the complex sentence. In this case, the reading times for the first sentence should be longer than the reading time for the corresponding part of the complex sentence. However, this was not the case. An ANOVA on the reading times for the first sentence and the corresponding part of the complex sentence, not reported in the Results section, showed that the differences were nonsignificant: 4 ms for the forward reading times (95% CI = −47.17, 38.31) and 47 ms for the go-past reading times (95% CI = −10.75, 92.06).

Finally, and more importantly, instead of attributing the different distributions of the reading times in the second sentence/clause to integration and inference, one might argue that words in the middle of a sentence are read faster than identical words at the start of a sentence (Region 2), and that the wrap-up for a complex sentence is longer than for a simple sentence (Region 3). The explanation for Region 2, however, is not very likely because if there is any evidence for an effect of serial position of words in a sentence on the reading time, it is for the first word (Haberlandt, 1984; cf. Vasishth, 2003), and the first word in both conditions was not included in Region 2. Moreover, both the conjunction and the full stop are segmentation markers, after which a new syntactic structure starts. Therefore, the comparison is not really between the words in the middle and the start of a sentence. The explanation for Region 3 in terms of sentence wrap-up is unlikely, as has been argued in the previous paragraph. To substantiate our interpretation of the data in this region in terms of inferences, we should demonstrate that the increase of reading times at the end of the sentence is actually due to inferential processing. As mentioned in the introduction, evidence for making the inference online may be obtained from the combined results of a reading task and a verification task in which the inferential information has to be verified as fast as possible (see also Singer & Halldorson, 1996; Singer, Halldorson, Lear, & Andrusiak, 1992; Singer, Harkness, & Stewart, 1997). The combination of an increase in reading time at the end of the sentence and a decrease in verification time, as a result of the presence of the conjunction, can be interpreted as evidence for online inferential processing. Because the verification task in this experiment was only used to make sure that participants read the texts carefully, no verification times were obtained that, in combination with the reading times, could serve to identify inferences.

Therefore, we conducted a second experiment in which participants read the same texts, but now had to verify inferential statements as fast as possible immediately after the text. If readers make the causal inference online if the conjunction is present but not if it is not, the verification of the inference after the text should be faster if the sentence contained the conjunction than if it did not. This result would qualify the reading time difference at the end of the causal relation sentence as a result of inferential processing.

EXPERIMENT 2

In Experiment 2, the same texts were used as in Experiment 1. In contrast to Experiment 1, the participants had to judge, as fast as possible, a verification statement after each text. The statements of the experimental texts contained the information that can be inferred from the causal sentences. The reading times

were measured in a self-paced reading technique, with small windows consisting of one or a few words.

Method

Participants. Forty-six students from Nijmegen University were paid to participate (32 women and 14 men, ranging in age from 18–25). Six participants, who had made four or more verification errors on experimental items, were excluded from the analyses; therefore, the data of 40 participants were analyzed.

Materials and design. The same texts were used as in Experiment 1. The texts were partitioned into small parts consisting of one or a few words, which were consecutively presented to the reader as readable text, whereas the rest of the text was masked by dashes. The regions of interest (Regions 1, 2, and 3; see Table 1) were presented in parts. For each text, a verification statement was generated. For the experimental texts, the statements contained the information that could be inferred from the causal relation sentence—that is, the major premise of the syllogism. For instance, the verification statement of the text in Table 1 read, "A traffic jam leads to a delay." The verification statements of the experimental texts were always true. For the filler texts, similar verification statements were created. However, these statements were not related to causal inferential processing, and were always false. The design of Experiment 2 was the same as that of Experiment 1.

Procedure

The readers were instructed to read the texts thoroughly, but quickly, in order to understand them. They were told that they had to judge a verification sentence after each text, and that they had to give their judgment as fast as possible, but without making errors. The texts were presented on a computer display. The responses to the reading task and the verification task were registered by a response panel with three buttons, the middle button for reading the texts and the outer buttons for the responses in the verification task. Before the actual presentation of the text, a signal consisting of the words "NEW TEXT" was shown on the screen. When the participant pressed the middle button on the response panel, the words disappeared and the text appeared with the first line at the position of the signal. The texts were presented with a self-paced reading method. Only one part of a sentence in the text was readable; and the remainder of the text, with the exception of spaces and punctuation characters, was replaced by dashes. When the middle button was pressed, the part that had just been read changed into a line of dashes, and the next part became readable, thus preventing

the reader from looking back in the text. When the last part had been read, the text disappeared from the screen and the word "VERIFICATION" appeared. It remained on the screen for 1 s, during which the participants moved their index fingers to the right-hand "true" and the left-hand "false" buttons. The participants had to indicate, as fast as possible, whether the verification sentence was true or false with respect to the text they had just read by pressing the appropriate outer button. The verification time was defined as the time from the beginning of the presentation of the verification statement until the button-press on one of the outer buttons. When the verification response had been given, the signal "NEW TEXT" appeared, indicating the start of a new text.

Results

Reading times. The reading times were analyzed in two ANOVAs: one with participants as a random variable ($F1$) and one with items as a random variable ($F2$). The $F1$ analysis contained *conjunction* (with the levels present and absent) as a within-subjects factor and *participants group* (with 2 levels) as a between-subject factor. The $F2$ analysis contained *conjunction* as a within-subjects factor and *items group* (with 2 levels) as a between-subject factor. Reading times of texts with an error on the verification task (7.0%; 7.1% and 6.9% in the conditions with and without conjunction, respectively) were excluded from the analyses.

ANOVAs were performed on the reading times of Regions 1, 2, and 3 of the second clause of the target sentence. The important regions were the middle part of the second clause, Region 2, and the final part of the second clause, Region 3. For all analyses, outliers exceeding 2.0 *SD*s from the participant and item means within condition were excluded (0.1% for Region 3). The mean reading times, their ANOVAs, and CIs are given in Table 4.

The analyses of Regions 1 and 2 showed an effect of conjunction: The reading times of these regions were shorter if the *conjunction* was present than if it was absent. In the analyses of Region 3, the last part of the second clause, there was also an effect of *conjunction*: The reading times of this region were longer if the conjunction was present than if it was absent.

Verification times. The same two ANOVAs, with the same factors, were performed on the verification times as on the reading times (see Table 4). Verification times of texts with an error on the verification task (7.0%) were excluded from the analyses. The data were checked for outliers exceeding 2.0 *SD*s from the participant and the item means within condition. No outliers were found.

There was an effect of *conjunction*: Verification times were shorter when the conjunction had been present than when it had been absent.

TABLE 4
Mean Region Reading Times (in Milliseconds) for Regions 1, 2, and 3; and Mean Verification Times (in Milliseconds), Their Analyses of Variance, and Confidence Intervals as a Function of Conjunction (Present or Absent) in Experiment 2

	Region			
Conjunction	*1*	*2*	*3*	*Verification*
Present	377 (50)	632 (153)	581 (123)	2317 (406)
Absent	414 (51)	671 (179)	547 (112)	2406 (467)
$F1$ (df; F)	1, 38; 41.80*	1, 38; 11.68*	1, 38; 8.74*	1, 38; 11.42*
$F2$ (df; F)	1, 22; 25.94*	1, 22; 7.45*	1, 22; 5.17*	1, 22; 15.81*
Min F' (df; F)	1, 47; 16.01*	1, 47; 4.55*	1, 46; 3.25#	1, 59; 6.63*
d (in milliseconds)	37	39	34	89
95% confidence interval	25.57, 48.97	16.08, 62.72	10.81, 57.35	35.78, 42.58

Note. Standard deviations are in parentheses.
*$p < .05$. #$p = .075$.

Discussion

Although a less natural reading task was used and participants were required to perform a verification task as fast as possible, the results of the reading times analyses in this experiment were similar to those of Experiment 1. The total reading times of the second clauses with or without the conjunction did not differ, as tested in an additional ANOVA (5 ms; 95% CI = −31.57, 42.21); but the processing of the middle part of the second clause, Region 2, took less time; and the processing of the final part of the sentence, Region 3, took more time if the conjunction was present than if it was absent. The effect found in the middle part of the second clause supported the notion that the conjunction facilitates sentence integration. It indicates to the reader how the two clauses should be integrated, and facilitates the processing of the words in the causal clause and their incorporation into the sentence representation. The effect in the final part of the sentence was assumed to be due to inferential processing: Readers make a world-knowledge inference by which the causal relation is justified. In this experiment, this claim was corroborated by the results of the verification task in which participants had to verify, as fast as possible, statements containing the inferential information: The results showed that participants were faster to verify the inferential information if the conjunction had been present in the text than if it had not. The conjunction elicited the inference to be made during the processing of the causal sentence, making its verification after the text easy. The combined results of the reading task and the verification task converge to the conclusion that the inference was indeed made during reading the end of the sentence.

GENERAL DISCUSSION

The results of both experiments can be summarized as follows: The presence of the conjunction *because* speeds up the reading of the words immediately following the conjunction, and slows down the reading of the last part of the subordinate clause. These results give support for two separate processes during reading: propositional integration and world-knowledge inference. First, the conjunction signals the way in which the words in the second clause have to be integrated into the sentence representation—namely, as a cause of the consequence in the first clause. Second, the conjunction indicates that there is a general causal relation that underlies the *because* sentence—that is, the major premise of a syllogism. The inference consists in deriving the causal relation expressed by the sentence and checking it against the knowledge of the world, thus justifying the causal relation. The effects have been observed in reading a target sentence that was embedded in a context comprising several sentences. Such a discourse better reflects normal reading circumstances than sequences of two sentences, as used in many experiments (e.g., Millis & Just, 1994; Mouchon et al., 1999).

In our experiments, the integration process and the inference process exhibit a chronological order. The integration process manifests itself quite early in the sentence, as soon as the conjunction has been encountered. In case of *because* sentences, the conjunction directs the reader to process the information in the subordinate clause in a causal sentence structure. The inference process manifests itself later in the sentence. However, this may not be interpreted as if the inference process is delayed. Just as integration occurs as soon as the information to be integrated is available, inferential processing can occur as soon as the information required for the inference is available. Given the content of the sentences used in these experiments, the inference can be made as soon as the information in the middle part of the clause is available. Only then can the matching against world knowledge take place. One may conclude that the integration and inference processes are immediate, incremental, and data-driven (cf. Kempen & Hoenkamp, 1987).

Experimental evidence for the different processes of integration and inference has also been obtained in experiments by Cozijn, Commandeur, Vonk, and Noordman (2011) in studies using a visual world paradigm. Listeners were presented with implicit causality verbs, such as *felt sorry*, in Dutch *because* sentences, as in, "The camel felt sorry for the octopus after the exam, because he could not get a pass mark for the work." Simultaneously, a visual display was presented with a drawing of the two protagonists (camel and octopus) and a distractor item (a piece of paper with a pencil representing the exam). The pronoun in these sentences is syntactically ambiguous: It can refer both to the camel and the octopus. As in this study, the conjunction *because* has an

integration function: It indicates a causal relation, and signals that the subordinate clause has to be interpreted as the expression of the cause of the event in the main clause. The interpersonal verb in "*x* felt sorry for *y*" has an implicit causality bias toward *y*: Readers prefer to attribute the cause of "felt sorry for" to the object, and not to the subject, of this verb. The integration function of *because* facilitates the processing of the words in the causal clause and the incorporation into the sentence representation. In combination with the causal bias of the interpersonal verb, this will lead the reader to make a co-referential relation between the octopus and *he.* This was what the eye-movement data of Cozijn et al. indeed showed: a preference to look at the octopus right after the pronoun. A second effect was obtained at the end of the sentence. As argued in this article, the understanding of the conjunction *because* requires an inference: the derivation of a major premise and matching it to world knowledge. In this example, this inference is, "A person who cannot get a pass mark is felt sorry for." This inference can be made as soon as the information in the subordinate clause is available. Our knowledge about exams is that not getting a pass mark is a suitable reason for being felt sorry for by someone else. Evidence for that inference was indeed obtained at the end of the sentence: When the sentence was congruent with the verb bias, as in "because he could not get a pass mark for the work," participants started looking at the correct referent (octopus) at an earlier moment than participants looked at the correct referent (camel) when the sentence was incongruent, as in "because he could not give a pass mark for the work," in which case, world knowledge had to redress the pronoun assignment.

We do not claim that our conclusions with respect to the understanding of the *because* sentences generalize to integration and inferences in general. However, we can speculate whether our results generalize to other conjunctions. A characteristic of our *because* sentences is that a general relation between the facts expressed by the clauses can be derived. This is true for other causal conjunctions and causal connectives as well, such as *therefore, so*, and *that is why*, as in, "John is a linguist; that is why he does not know much about statistics." Also, in sentences with a concessive conjunction and a contrastive conjunction that express a denial of expectation, a general causal relation can be derived. Examples are, "Although John is a linguist, he knows much about statistics," and "John is a linguist, but he knows much about statistics." The expectation is based on an assumed relation between linguists and not knowing much about statistics. This relation is denied with respect to John. In these kinds of sentences, we predict the same integration (speeding up) and inference (slowing down) effects as we found for the *because* sentences. However, this prediction is not easy to prove. For instance, it is not very surprising to find shorter reading times after a contrastive conjunction, if these times are compared with a condition in which the conjunction is absent, because the sequence of two contrastive sentences without conjunction is rather peculiar. Take, for instance,

the following sequence (from J. D. Murray, 1995): "Rudy and Tom laughed with each other on the bus to the amusement park. They didn't speak to one another for the rest of the day." Without linguistic marking, the denial of expectation in the second sentence is quite unexpected, and most certainly will lead to longer reading times. The reason is that we are inclined to interpret sequences of sentences that are not connected by a conjunction in a causal way, but not in a concessive or contrastive way.

The conjunction *but* can also express a semantic opposition, as in, "John is small, but Pete is tall." There is no general relation underlying this sentence, as in our causal sentences. Therefore, we do not predict a world-knowledge inference effect, but we do predict a propositional integration effect. This can be tested by manipulating the presence of the conjunction (the conjunction *but* can be omitted in a semantic opposition).

Sentences with a temporal connective (e.g., *before, after*, or *when*) and sentences with an additive connective (e.g., *and*) are frequently interpreted in a more informative way than the literal meaning allows for. Levinson (1983) formulated the principle of informativeness: "[R]ead as much into an utterance as is consistent with what you know about the world" (pp. 146–147). In the sentence, "He turned on the switch and the motor started," the conjunction *and* will be interpreted in a temporal and causal way (see also Oversteegen, 1996). Similarly, a causal interpretation is possible for temporal connectives, as in, "After Mary had played tennis for two hours, she was exhausted." Therefore, if the temporal conjunctions are understood in a causal way, then we predict a propositional integration effect and a world-knowledge inference effect for these sentences.

It should be noted that we only studied causal sentences that consisted of two clauses, both of which expressed a state of affairs in the world. Accordingly, the relations were content relations and not epistemic relations (Sweetser, 1990; for the same distinction in different terms, see Halliday & Hasan, 1976; Sanders, Spooren, & Noordman, 1992; Traxler, Sanford, Aked, & Moxey, 1997). An epistemic causal relation, such as, "John is not at his work, so he must be ill," expresses a conclusion of the speaker, and this conclusion is based on a content causal relation (if you are ill, you are not going to your work). Epistemic relations require more processing time than content relations (Noordman, 1979, pp. 65–112; Traxler et al., 1997). In understanding an epistemic causal relation, both the underlying content causal relation and the embedding epistemic proposition (from knowing . . . , you may conclude that . . .) have to be processed. If the content causal relation is processed, one may predict that in processing the epistemic sentence, both the integration process and the causal inference process take place.

In this article, we made a distinction between the propositional integration process and the world-knowledge inference process in understanding *because*

sentences. The experimental results in this study indicate that propositional integration and world-knowledge inference are indeed two identifiable processes in understanding *because* sentences. We argue that this distinction corresponds to the distinction between relations internal to the representation and relations with a model of the world—a distinction that is rather fundamental in the study of language.

Understanding a discourse implies that the relations between parts of the text are made, as well as the relations between the text and a model of the world. There are texts for which establishing a relation between sentences is rather straightforward, but establishing the relation with the world is not so obvious. An example is the beginning of a novel:

> Always again that dream of a happy family. They have arrived in the country of the soft winters and the warm summers and enjoy a meal in the open air, in a patio surrounded by grapes or under the light green of a translucent acacia. (Smabers, 2009, p. 5)

The two sentences are related to each other in the internal representation of the discourse by means of a referential relation between *they* and *family*. However, it is not clear how the sentences relate to the world and what mental model should be constructed. The dimensions of the world model—such as persons, time, and place—still have to be filled in (Zwaan & Radvansky, 1998). This example illustrates the distinction we make between the two kinds of relations. Similarly, when Johnson-Laird (1983) discussed the comprehension of discourse, he argued that the reader not only identifies relations in the discourse, such as referential relations, but also evaluates whether the information in the discourse corresponds to the world. With respect to this latter aspect, Johnson-Laird referred to plausibility: "Plausibility depends on the possibility of interpreting the discourse in an appropriate temporal, spatial, causal, and intentional framework" (p. 371). Guenthner (1989) made the distinction between relations internal to the representation and relations with a model of the world in terms of D-relations (for *discourse* relations) and T-relations (for *truth* relations). D-relations govern the way representations may be extended or modified in the course of a discourse. T-relations involve reference to the world in terms of truth, probability, and possibility. The same distinction is apparent in the way semantics is defined: "Essentially, semantics is concerned with the ways the truth values of sentences depend on the meanings of their parts and the ways the truth values of different sentences are related" (Gamut, 1991, p. 92). In logic, a fundamental distinction that goes back to Aristotle is made between the trustworthiness of premises, which refers to the relation of the premises to the world in terms of truth or probability; and a logical relation, which guarantees that the trustworthiness of the premises transfers to the conclusion (Kamp & Reyle, 1993, pp. 13–15).

The distinction between relations internal to the representation and relations with a model of the world is also made in linguistic models of discourse—for example, in the Discourse Representation Theory (DRT) of Kamp and Reyle (1993), in the Segmented Discourse Representation Theory (SDRT) of Asher (1993), and in the Logical Descriptive Grammar (LDG) of Van Leusen (2007). In DRT and SDRT, the meaning of sentences and the integration between sentences are formally represented in the construction of referents and DRT-conditions in the DRT-boxes. The relation of the text with the world—in particular, the assignment of truth values—is achieved in a process called embedding in a model of the world. In LDG, two processes are distinguished, which we illustrate for the processing of conjunctions. First, words trigger appropriateness conditions. In case of a causal conjunction, this condition expresses that in the local context of interpretation, a causal relation can be derived. The appropriateness condition is part of the conjunction, and understanding the appropriateness condition is part of the linguistic processing. Second, the appropriateness condition is tested against knowledge of the world. The assumption of a causal relation is then accommodated in the background knowledge of the comprehender. It is interesting to note that this latter process can occur in two different ways in LDG: global accommodation and content modification. This distinction corresponds to our distinction (Noordman & Vonk, 1992; Simons, 1993) between an inference process by experts (activating available knowledge) versus the inference process by novices (adding new knowledge).

In summary, we made a distinction between the processes of propositional integration and world-knowledge inference in understanding *because* sentences. Propositional integration refers to the process by which the comprehender establishes the type of relation between the two clauses or sentences; world-knowledge inference refers to the process of deriving the general causal relation and checking it against the comprehender's world knowledge. In two experiments, evidence was obtained for propositional integration and world-knowledge inference as two identifiable processes during the understanding of *because* sentences. In these experiments, propositional integration occurs as soon as the second clause is processed, and is facilitated by the presence of the conjunction. World-knowledge inference occurs as soon as the information in the second clause is available, and is triggered by the conjunction.

REFERENCES

Asher, N. (1993). *Reference to abstract objects in discourse.* Dordrecht, The Netherlands: Kluwer Academic.

Bird, K. D. (2002). Confidence intervals for effect sizes in analysis of variance. *Educational and Psychological Measurement, 62*, 197–226.

Cozijn, R. (1992). Inferential processes during the construction of a coherent text representation. In M. van Oostendorp (Ed.), *CLS conference 1992* (pp. 1–14). Nijmegen/Tilburg, The Netherlands: Center for Language Studies.

Cozijn, R. (2006). Het gebruik van oogbewegingen in leesonderzoek [The use of eye movements in reading research]. *Tijdschrift voor Taalbeheersing, 28*, 220–232.

Cozijn, R., Commandeur, E., Vonk, W., & Noordman, L. G. M. (2011). The time course of the use of implicit causality information in the processing of pronouns: A Visual World Paradigm study. *Journal of Memory and Language, 64*, 381–403.

Crothers, E. J. (1979). *Paragraph structure inference.* Norwood, NJ: Ablex.

Fletcher, C. R., & Chrysler, S. T. (1990). Surface forms, textbases, and situation models: Recognition memory for three types of textual information. *Discourse Processes, 13*, 175–190.

Gamut, L. T. F. (1991). *Logic, language, and meaning.* Chicago, IL: University of Chicago Press.

Guenthner, F. (1989). Discourse: Understanding in context. In H. Schnelle & N. O. Bernsen (Eds.), *Logic and linguistics: Research directions in cognitive science: European perspectives* (Vol. 2, pp. 127–142). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Haberlandt, K. (1984). Components of sentence and word reading times. In D. E. Kieras & M. A. Just (Eds.), *New methods in reading comprehension research* (pp. 219–251). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Halliday, M. A. K., & Hasan, R. (1976). *Cohesion in English.* London, England: Longman.

Irwin, D. E. (1998). Lexical processing during saccadic eye movements. *Cognitive Psychology, 36*, 1–27.

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

Kamp, H., & Reyle, U. (1993). *From discourse to logic: Introduction to modeltheoretic semantics of natural language, formal logic, and Discourse Representation Theory.* Dordrecht, The Netherlands: Kluwer Academic.

Katz, B., Müller, K., & Helmle, H. (1987). Binocular eye movement recording with CCD arrays. *Neuro-Ophtalmology, 7*, 81–91.

Kempen, G., & Hoenkamp, E. (1987). An incremental procedural grammar for sentence formulation. *Cognitive Science, 11*, 201–258.

Kintsch, W. (1998). *Comprehension: A paradigm for cognition.* Cambridge, UK: Cambridge University Press.

Kintsch, W., & Van Dijk, T. A. (1978). Toward a model of text comprehension and production. *Psychological Review, 85*, 363–394.

Koornneef, A. W. (2008). *Eye-catching anaphora.* Unpublished doctoral thesis, Utrecht University, The Netherlands.

Levinson, S. C. (1983). *Pragmatics.* Cambridge, UK: Cambridge University Press.

Millis, K. K., Golding, J. M., & Barker, G. (1995). Causal connectives increase inference generation. *Discourse Processes, 20*, 29–49.

Millis, K. K., & Just, M. A. (1994). The influence of connectives on sentence comprehension. *Journal of Memory and Language, 33*, 128–147.

Mouchon, S., Ehrlich, M.-F., & Loridant, C. (1999). Effets immédiats ou différés du connecteur "parce que" dans la compréhension de phrases? Réexamen du modèle de Millis et Just (1994) [Immediate or delayed effects of the connective "parce que" (because) in understanding sentences? Re-examination of the model by Millis and Just (1994)]. *L'Année Psychologique, 99*, 239–269.

Murray, J. D. (1995). Logical connectives and local coherence. In R. F. Lorch & E. J. O'Brien (Eds.), *Sources of coherence in reading* (pp. 107–125). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Murray, W. S. (2000). Sentence processing: Issues and measures. In A. Kennedy, R. Radach, D. Heller, & J. Pynte (Eds.), *Reading as a perceptual process* (pp. 649–664). Oxford, UK: Elsevier.

Noordman, L. G. M. (1979). *Inferring from language.* Berlin, Germany: Springer.

Noordman, L. G. M., & Vonk, W. (1992). Reader's knowledge and the control of inferences in reading. *Language and Cognitive Processes, 7*, 373–391.

Noordman, L. G. M., Vonk, W., & Kempff, H. J. (1992). Causal inferences during the reading of expository texts. *Journal of Memory and Language, 31*, 573–590.

Ochs, E. (1979). Planned and unplanned discourse. In T. Givón (Ed.), *Syntax and semantics (XII): Discourse and syntax* (pp. 51–80). New York, NY: Academic.

Oversteegen, L. E. (1996). *Dutch temporal connectives* (No. Dandelion R1.3.2a). Nijmegen/Tilburg, The Netherlands: Center for Language Studies.

Sanders, T. J. M., Spooren, W. P. M., & Noordman, L. G. M. (1992). Towards a taxonomy of coherence relations. *Discourse Processes, 15*, 1–35.

Segal, E. M., Duchan, J. F., & Scott, P. J. (1991). The role of interclausal connectives in narrative structuring: Evidence from adults' interpretations of simple stories. *Discourse Processes, 14*, 27–54.

Simons, W. H. G. (1993). *The control of inferences by the knowledge of the reader.* Unpublished doctoral thesis, Radboud University Nijmegen, The Netherlands.

Singer, M., & Halldorson, M. (1996). Constructing and validating motive bridging inferences. *Cognitive Psychology, 30*, 1–38.

Singer, M., Halldorson, M., Lear, J. C., & Andrusiak, P. (1992). Validation of causal bridging inferences in discourse understanding. *Journal of Memory and Language, 31*, 507–524.

Singer, M., Harkness, D., & Stewart, S. T. (1997). Constructing inferences in expository text comprehension. *Discourse Processes, 24*, 199–228.

Singer, M., & O'Connell, G. (2003). Robust inference processes in expository text comprehension. *European Journal of Cognitive Psychology, 15*, 607–631.

Smabers, N. (2009). *De man van gas en licht* [The man of gas and light]. Amsterdam, The Netherlands: Bezige Bij.

Sweetser, E. (1990). *From etymology to pragmatics. Metaphorical and cultural aspects of semantic structure.* Cambridge, UK: Cambridge University Press.

Traxler, M. J., Sanford, A. J., Aked, J. P., & Moxey, L. M. (1997). Processing causal and diagnostic statements in discourse. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 23*, 88–101.

Van Leusen, N. (2007). *Description grammar for discourse.* Unpublished doctoral thesis, Radboud University Nijmegen, The Netherlands.

Vasishth, S. (2003). *Working memory in sentence comprehension: Processing Hindi center embeddings.* New York, NY: Garland.

Vonk, W., & Cozijn, R. (2003). On the treatment of saccades and regressions in eye movement measures of reading time. In J. Hyönä, R. Radach, & H. Deubel (Eds.), *The mind's eye: Cognitive and applied aspects of eye movement research* (pp. 291–312). Oxford, UK: Elsevier.

Zwaan, R. A., & Radvansky, G. A. (1998). Situation models in language comprehension and memory. *Psychological Bulletin, 123*, 162–185.