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Causality in on-line discourse processing: What eye-tracking reveals about the role of causal relations and connectives

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Abstract

This study investigated 3 unsettled issues in the literature concerning the cognitive status of the coherence relation, namely, the effect of *relation* on text processing, the effect of *connective* on mental representation, and the interaction between *relation* and *connective* in text comprehension. Meanwhile, the study aimed at distinguishing several theoretical hypotheses closely related to these issues, that is, the *causality-by-default hypothesis* vs. the *causal complexity hypothesis*, and the *incremental integration model* vs. the *delayed integration model.*

For these goals, an eye-tracking experiment was conducted on simple narrative materials which allowed a direct comparison between causal and temporal relations. In the experiment, two within-subject factors were manipulated: *relation* (2 levels: causal vs. temporal) and *connective* (3 levels: dus 'so', toen 'then', implicit). By factor combination, we arrived at six conditions: the causal-*dus* condition, the causal-*toen* condition, the causal-implicit condition, the temporal-*dus* condition, the temporal-*toen* condition, and the temporal-implicit condition. The experimental texts were constructed to be maximally identical across the two relations, and to be different only in the coherence marking between the implicit and explicit versions.

In the reading task, overall causal relations were processed faster than temporal relations, and this effect emerged well before the end of the target sentence, in support of the *causality-by-default hypothesis* and the *incremental integration model*. Besides, an interaction effect was found at the end of the target sentence in *regression path duration*, showing that the effect of *relation* was modulated by the effect of *connective*. The size of the reading-time difference was enlarged by the connective *dus* (i.e. causal-*dus* < temporal-*dus*, 323 ms difference; whereas causal-implicit < temporal-implicit, 112 ms difference), and was reduced by the connective *toen* (i.e. causal-*toen* < temporal-*toen*, 45 ms difference). Moreover, another interaction effect was found immediately following the target sentence in *regression path duration*. The effect of *relation* disappeared in the *toen* conditions (i.e. causal-*toen*= temporal-*toen*) while persisting in the *dus* and impilicit conditions (i.e. causal-*dus* < temporal-*dus*, causal-implicit < temporal-implicit). These observed interaction effects suggest that coherence relations and connectives interact with each other during the on-line processing: When the connective matched the relation, the reading process was facilitated; when the connective did not match the relation (i.e. the temporal-dus condition), the reading process was disrupted.

In the verification task, no main effect of connective or interaction effect was observed in terms of verification accuracy. This finding suggests that the mental text representation is not influenced by connectives, and that the on-line interaction between *connective* and *relation* does not affect the final text representation. There was an interaction effect on response latency: Response time was significantly shorter in the causal-*dus* condition than in the other conditions. However, this effect was restricted to the causal connective *dus* in the causally related texts. I would rather interpret it as a facilitating role of causal connectives (when properly used) in retrieving text representation from memory.

These results, together with the earlier results reported in the literature, lead us to conclude that

coherence relations are cognitive entities. They influence both discourse processing and discourse representation. Moreover, linguistic markers of coherence relations function as processing instructions, guiding the reader to integrate the consecutive sentences by means of a coherence relation. Linguistic marking does not affect the final representation of the text, at least when readers have sufficient world knowledge concerning the texts. Finally, coherence relations and linguistic markers are independent coherence variables, they interact with each other during the processing.

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1. Introduction

In research on discourse processing and text comprehension, it has been widely acknowledged that readers have to construct a cognitive representation of the information described in a text in order to comprehend the text successfully (see among many others, Oakhill & Garnham 1992; Gernsbacher & Givón 1995; Sanders & Noordman 2000; Van Dijk & Kintsch 1983). A crucial property of the cognitive representation is that it is coherent (Hobbs 1979; Kehler 2002; Sanders, Spooren & Noordman 1992), which is partially[1] achieved by relating the different information units in the text by means of coherence relations. Coherence relations refer to the meaning relations which connect two text segments, such as cause –consequence, list or collection, and temporal sequence. Examples are presented in (1), (2), and (3).

(1) The sun was shining. The temperature rose.
(2) A robin is a singing bird. Robins live in woods.
(3) John picked up the phone. He dialed the number.

Understanding these sentence pairs requires establishing the causal, additive, and temporal relations, respectively. This is not achieved merely by comprehending each word, phrase, and sentence, because a coherence relation is an aspect of the meaning of two or more discourse segments that cannot be described in terms of the meaning of the segments in isolation (see Sanders et al. 1992). To establish the coherence relation in a text, readers need to resort to the text as well as their world knowledge (see Noordman & Vonk 1997). In (1), for example, the causal relation that holds between the segments is not described by either segment in isolation. The reader has to activate the knowledge that a shining sun always makes the temperature high to compute the causal relation and to construct a coherent mental representation accordingly. Sometimes, but not always, a coherence relation is made explicit by linguistic markers such as connectives (e.g. *because*, *then*, *and*) and signaling phrases (i.e. *as a result*, *the next morning*, *in addition*). Sometimes, a linguistic marker may be used in more than one coherence relation, see (4) in which the connective *and* is used in both a causal and an additive relation. We call the case of such connectives like *and* in (4)a underspecified in this respect: In principle they express one relation (i.e. the additive relation in [4]a)，but allow the inference of another (i.e. the causal relation in 4[a]).

(4) a. *Causal relation*
John turned the switch, and the motor started.
b. *Additive relation*
Bill is a musician, and he is a poet as well.

(5) *Concession*

[1] Generally speaking, referential coherence can also contribute to the coherence in the text representation. (Sanders & Spooren 2001) That is, the information units in the text may be connected by repeated reference to the same object. For example, *Dan lived near a bar. Every night he went there*.

a. He is a great basketball player, even though he is small.
b. # He is a great basketball player, and he is small.

What, then, is the relationship between coherence relations and linguistic markers? Of course there is no one-to-one mapping between them. At the same time, it is clear that there is a restriction on the use of linguistic markers, which can be described into coherence relations. For instance, a connective like *and* can express many relations such as additive, temporal, and even causal relations, but it cannot express the relation of concession (see [5]b). The question is: How exactly do linguistic markers interact with coherence relations? We will find an answer in this study.

The above discussion suggests an agreement in the literature that constructing a coherent representation of a text requires that coherence relations can be established between text segments on the basis of the text and the reader's world knowledge. In this view, coherence relations are not merely analytic tools as claimed by Grosz and Sidner (1986). Nor do they lie exclusively within the text. Rather, coherence relations are part of the mental representation of the text. They are cognitive entities. This conclusion has the following implications. Firstly, if coherence relations actually have cognitive relevance, it can be expected that they influence the real-time cognitive processes of discourse interpretation as well as the final cognitive representation that readers have built after reading. Secondly, one may expect that the linguistic markers of coherence relations influence discourse interpretation as well. Thirdly, assuming that *relation* and *linguistic markers* are independent coherence variables, it could be expected that they interact with each other during the processing. A crucial question concerns how this interaction (if any) is reflected in the on-line processing and the final text representation.

With respect to the first implication that the nature of *relation* should affect discourse processing and discourse representation, a great deal of converging evidence has been obtained for the representational advantage of a specific type of causal relation. A consistent result in research with short narratives is that causally connected information was remembered better than non-causually related information (Schank 1975; Black& Bern 1981; Trabasso& Sperry 1985; Trabasso & van den Broek 1985; Van den Broek 1990). At the same time, classical findings during processing show how causally related information is read faster (Haberlandt & Bingham 1978) and reading times decrease when causality increases (Keenan et al. 1984; Myers, Shinjo, & Duffy 1987; Wolfe et al. 2005). Sanders and Noordman (2000) generalize the processing and representational advantage of causal relations to expository texts. In a self-paced reading experiment using newspaper-like texts, it was found that sentences that were causally related to the previous context were read significantly faster than identical sentences that were related in an additive way to the previous context. Meanwhile, it was found that readers verified statements faster and more adequately, and their recall was superior in the causally related expository texts.

Concerning the role of linguistic markers, there is indeed much empirical support for the position that connectives and other linguistic coherence markers play a facilitating role during the reading process (Gaddy, van den Broek & Sung 2001): They lead to faster processing of directly following text segments (Bestgen & Vonk 1995; Britton, Glynn, Meyer & Penland 1982; Haberlandt 1982; Sanders & Noordman 2000). With respect to the influence of explicit coherence markers on the text representation afterwards, the situation is not so clear. On the one hand, some results show that linguistic marking of coherence relations improves the mental text representation. This becomes apparent from better recall performance (Loman & Mayer 1983; Lorch & Lorch 1986; Meyer, Brandt & Bluth 1980), a faster and more accurate response on a prompted recall task (Millis & Just 1994), and better answers to comprehension questions (Degand, Lefèvre & Bestgen 1999; Degand & Sanders 2002). On the other hand, there are a number of studies that indicate that linguistic markers do *not* have this facilitating role, as shown by a lack of effect on the amount of information recalled (Meyer 1975; Sanders & Noordman 2000) or no better answers on comprehension questions (Spyridakis & Standal 1987). Some authors even claim a negative impact of connectives on text comprehension (Millis, Graesser & Haberlandt 1993). In Millis et al (1993), subjects read and then recalled passages with either no connectives, temporal connectives (*before/and then*), causal connectives (*which caused/which enabled*), or intentional connectives (*in order that/so that*). On the basis of the experimental results, the authors concluded that connectives interfered with text comprehension: The recall for passages without connectives was higher than the recall for passages with connectives.

Most researchers studied the effect of *relation* and the effect of *linguistic markers* separately; very few compared these effects and investigated how they interact with each other in text comprehension. Sanders and Noordman (2000) did some comparison between the effect of *relation* and the effect of *linguistic markers*, and shed some light on the third implication discussed above: Assuming that *relation* and *linguistic markers* are independent coherence variables, it could be expected that they interact with each other during the processing. In an experiment using reading, verification, and free recall tasks, they found that coherence relations and linguistic markers play independent roles in text comprehension. Coherence relations affected text processing, verification and recall, whereas explicit marking of the relations resulted in faster processing but did not affect recall. Accordingly, they concluded that coherence relations are an indissoluble part of the cognitive representation itself, whereas linguistic markers like connectives and signaling phrases are merely expressions of these relations that guide the reader in selecting the right coherence relation. However, the authors did not report any interaction effect between coherence relations and linguistic markers during the reading process, during the verification task, or during the recall task.

In sum, not all the three theoretical issues are yet corroborated by the previous studies. Especially, it is still unclear whether linguistic markers affect the final cognitive representation that readers have constructed after reading. Also, little experimental work studies how the coherence relation and the connective interact with each other during and after the construction of the cognitive representation of the text. Moreover, although it was found that causally related texts were read faster than additively related texts, several important questions remain unanswered. A crucial one is: Why are causal relations processed faster?

In view of all these concerns, this study aims to investigate the unsettled issues in a new experiment. On the basis of the investigation, it is expected to discern the role of the relation and the linguistic marker, respectively, and their interaction in discourse interpretation. Before presenting the experimental design, I will first review the relevant theoretical issues and the empirical data associated with them in more or less detail.

1.1. The role of causal relations —Causality-by-default hypothesis and Causal complexity hypothesis

As briefly mentioned in the introduction, many prior studies have found that causal coherence relations play an important role in on-line text processing as well as in final text representation. In terms of the final representation, empirical results consistently show that causality improves the coherence of the mental representation of the text. In terms of the online processing, the effects of causal relations may be categorized into the following three respects. Firstly, one line of research has compared the reading times of unrelated texts with the reading times of causally related texts, and found that causally related information was read much faster than when this information was not related to the preceding text information. Haberlandt & Bingham (1978), for example, studied the processing of unrelated triples (e.g. *Brian punched George. George liked the doctor. The doctor arrived.*), and causally related triples (e.g. *Brian punched George. George called the doctor. The doctor arrived.*), and found that reading times were longer for the third sentence of unrelated triples than for the third sentence of causally related ones, although these sentences were identical. This result is among the first types of evidence for the cognitive effect of causal relation on text processing. Secondly, another line of research with narrative texts focuses on the effect of different levels of causality on the processing of simple narratives, and found that different levels of causal relations were processed differently. In these experiments, an identical target sentence was embedded in three different contexts, resulting in three levels of causality: high level, moderate level, and low level of causality (see [6] which is taken from Keenan, Baillet, and Brow, 1984). Both the processing and representational differences were observed: The positive effect of causal relations on memory for sentences is greatest for moderate levels of causality; and the reading time decreases when the causality increases (Keenan, Baillet, and Brow 1984; Myers, Shinjo, and Duffy 1987). These results are suggestive of the processing advantage of causal relations in text processing. The third line of research began to compare the processing of causal relations with the processing of the additive relation, and found that causal relations were processed faster than additive relations. A typical experiment was conducted by Sanders and Noordman (2000) with newspaper expository texts. The experiment manipulated the coherence relation between *problem-solution* (a type of causal relation) and *list* (also called additive relation) by embedding an identical target sentence in different contexts (see [7]). They found that causally related texts were read faster than additively related texts. Meanwhile, causally related texts were verified faster and more accurately, and were recalled superior.

(6) a. *High level causality context (level 1)*
Joey's big brother punched him again and again.
b. *Intermediate level causality context (level 2)*
Racing down the hill, Joey fell off his bike.
c. *Intermediate level causality context (level 3)*
Joey's crazy mother became furiously angry with him.
d. *Low level causality context (level 4)*
Joey went to a neighbor's house to play.
e. *Target sentence*
The next day his body was covered with bruises.

(7) a. *Problem-solution context*

… Because of heavy traffic, crossing the street has become very dangerous.

b. *List context*

… The exit of the highway between Groningen and the German border, on the east of Veendam, will be re-asphalted in spring.

c. *Target sentence*

The construction of a subway in the center of Veendam will begin next year.

These findings take us to the crucial question: If causal relations indeed show a processing advantage, how should this be accounted for theoretically? It is widely acknowledged in logic and linguistics that causal relations presuppose additive relations and thus are semantically more complex. From the point of view of formal semantics, if 'A because B' is true, we must first presuppose 'A and B' is true. Accordingly, one may predict that causal sentences require extra processing time, since extra cognitive effort needs to be involved. This is the basic idea of the *causal complexity hypothesis.* On the other hand, one may assume that causal relations are cognitively more preferable. When no clear connective or other lexical cue is present, the reader will start out assuming the relation between two consecutive sentences is a causal relation (given certain characteristics of two discourse segments) and only arrive at an additive relation if no causal relation can be established. Subsequently, causally related information will be processed faster. This is the essence of the *Causality-by-default hypothesis* proposed by Sanders (2005).

To evaluate the above hypotheses theoretically, we found that they are equally plausible. The *causal complexity hypothesis* is in line with the linguistic and acquisition predictions. The results from both naturalistic (Bloom et al., 1980; Bloom, 1991; Evers-Vermeul & Sanders, 2009) and experimental studies (Piaget, 1924/1969; Katz & Brent, 1968) of first language acquisition show that additive relations are acquired before causal ones, and that additive connectives are acquired before causal connectives. This corroborates the idea that causal relations are cognitively more complex than additive relations. Thus we may expect the causal relation to require more cognitive effort and more processing time. Besides, it is in line with the *Informativeness principle* in Levinson (1983), who presents a process model on the basis of examples like *He turned on the switch and the motor started.* He argues that the listener or reader first checks the possibility of the least informative interpretation (i.e the additive relation); if possible, they will interpret the events as temporally successive; and perhaps end up with the most informative interpretation (i.e. the causal relation) allowed by the world knowledge (see also Levinson, 2000). This order predicts that an additive relation requires less decision than the temporal and the causal interpretations, and thus takes less processing time. The *Causality-by-default hypothesis*, on the other hand, also conforms to the basic idea in the *Informativeness principle* that readers strive to amplify the informational content of the discourse by finding the most specific interpretation, but the reverse procedures were assumed. According to the *Causality-by-default hypothesis*, the most informative relation, that is the causal relation, should be cognitively more preferable because readers aim for the richest interpretation. Thus, the reader will start out assuming the relation between two consecutive sentences is a causal relation (given certain characteristics of two discourse segments) and only arrive at an additive relation if no causal relation can be established. Another similar explanation for this causal preference can be found in semantic and pragmatic theories. For instance, *the principle of Maximize discourse coherence* (Asher & Lascarides 1998) claims that the informational-richer causal relation (i.e. *explanation*) is to be preferred over non-causal ones. "Intuitively, one prefers an interpretation of a discourse that offers explanations of intentional behaviour […] to an interpretation of the discourse where such behaviour is left unexplained […]. We can model this via the partial order of rhetorical relations: Explanation > Background in this case." (107). Moreover, it is not difficult to find an origin for the *Causality-by-default hypothesis* in the theory of general cognition, if we assume that causal relations are better organized than other coherence relations. In view of a general cognitive principle, the *Gestalt psychology* that human mind and brain prefer structure, pattern, and organization to randomness, the better-organized causal relation should be cognitively preferable, giving rise to a cognitive tendency to relate events or states causally.

However plausible these two hypotheses may be, so far no direct empirical evidence has been achieved to support either the *causality-by-default hypothesis* or the *causal complexity hypothesis.* The above discussed studies are only suggestive of the *Causality-by-default hypothesis*. The first line of research such as Haberlandt & Bingham (1978) does not contribute much to this issue. Although it did show the cognitive effect of causal relations on text processing, it did not compare the processing of causal relations with the processing of other coherence relations. Likewise, although the second line of research was suggestive of the processing advantage of causal relations on text processing. It could be argued that it was only the degree of relatedness, rather than the nature of the causal relation itself, that matters during processing, because the high, moderate, and low levels of causality may be assumed to belong to the same category of relations. The third line of research seems to have provided the most convincing evidence for the *causality-by-default hypothesis*. A type of causal relation, i.e. the problem-solution relation, was found to be processed faster than additive relations. However, as acknowledged by the authors themselves, an alternative account for these results is also possible (see Mulder 2008): the *Schematic structural expectation hypothesis*, which assumes that the structure of the text under consideration triggers expectations regarding the text passages yet to come. In the case of problem-solution structures in the experiment, the description of a negative situation in (7)a would probably trigger the expectation for an action, like (7)c, undertaken to take away this negatively evaluated situation and result in a new positive situation, and therefore the solution sentence (7)c will be read faster, especially because no such expectations exist for list relations like (7)b. This explanation would state an alternative to the *Causality-by-default* interpretation. For this reason, it could be argued that Sanders and Noordman (2000) did not offer direct evidence for the idea that the nature of causal relation facilitates on-line text processing by itself.

To address the problems discussed in this section, the present study aims to re-examine the effect of causal relations on discourse processing in simple narratives which do not allow the interference of the *Schematic structural expectation hypothesis*, and meanwhile seeks to solve the *Causality-by-default* vs. the *causal complexity* discussion with new empirical data.

1.2. The role of connectives — Incremental integration model and Delayed integration model

Ever since Ducrot (1980) and Lang (1984), there have been linguistic accounts of connectives as operating instructions. The basic idea is that a connective serves to relate the content of connected segments in a specific type of relationship. In psycholinguistics, it has been proposed that the linguistic indicators of coherence relations guide the processing of the relations by providing the reader with processing instructions (Britton, 1994). This idea was developed by Millis and Just (1994) into a c*onnective integration model*. According to this Model, the connective instructs and guides the reader to integrate the clauses in a way denoted by the meaning of the connective. When there is no connective, the reader is not obliged to integrate the clauses in the same way (or at all) as when the connective is present. This assumption is in fact quite in line with one of the major functions of connectives as identified by Noordman and Vonk (1997)[2]: the function of a connective as an integration device. The connective indicates how the current information has to be integrated with the previous information. To be more precise, the connective specifies to the reader that a specific coherence relation holds between the clauses and instructs the reader to integrate the clauses by means of that relation. Moreover, according to Noordman and Vonk (1997), the causal relation is constructed during the integration process. Therefore, we may assume that the integration process proceeds simultaneously with the construction of the relation.

The *connective integration model* is generally consistent with the empirical data collected from various on-line processing studies of connectives. The major source of evidence is the observation that subjects spent less time reading a sentence when it was introduced by a connective than when the connective was absent (see Haberlandt, 1982; Cozijn, 2000). The connective facilitates the processing of the immediate following information by specifying the way in which the clauses should be integrated into a coherent representation. The other source of support is the observation that readers adopt different processing strategies for different types of connectives. Townsend (1983) reported that when a connective signals a clear causal/temporal ordering of the clauses, the clauses are readily incorporated into the existing text representation. However, if the connective disrupts a clear causal/temporal ordering, processing is temporally suspended until subsequent disambiguating information is found. All these results suggest that linguistic markers play an important role in on-line text processing.

There is less agreement in the literature as to the time-course of the integration process. In their probe-recognition experiment, Millis and Just (1994) compared the probe recognition time between the connective explicit and implicit conditions. The verb of the first clause was measured at two locations: one word after the connective or immediately after the last word of the second clause. It was found that the connective decreased the probe recognition time when the probe occurred at the end of the sentence. When the probe occurred in the earlier location, however, the connective increased the probe times. On the basis of these findings, Millis and Just (1994) proposed that readers set the representation of the first sentence aside in working memory as they construct a representation of the second sentence, and they do not reactivate the representation of the first sentence, compute the relation, and integrate representations until the second sentence is fully represented. This is the so-called *delayed integration model*.

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[2] Noordman and Vonk (1997) proposed that the causal connective *because* has three different functions during processing: the segmentation function, the integration function, and the inference function.

A different model was put forward by Traxler, Bybee and Pickering (1997) on the basis of the eye-tracking evidence obtained from their experiment. In that experiment, the authors compared the processing of diagnostic statements and plain backward causal statements. The diagnostic statements were related in a claim-argument relation like, *Heidi could imagine and create things because she won first prize at the art show.* The backward causal statements were of the consequence-cause relation. For example, *Heidi felt very proud and happy because she won first prize at the art show.* Traxler et al. demonstrated that diagnostic statements should take longer to comprehend than plain causal statements, because diagnostic statements require an inference process to establish the nature of the causal consequence or conclusion. The crucial point was when the difficulty associated with the diagnostic statements occurs. It was found that the reading time differences emerged long before the end of the sentence, which actually implied that readers began to compute the relation and integrate the representations long before the end of the sentence. Therefore, Traxler, Bybee and Pickering (1997) proposed that the construction of an integrated representation of two clauses could proceed incrementally. This is the so-called *incremental integration model.*

Traxler, Bybee and Pickering (1997) attributed the differences between the Millis and Just (1994) data and their data to the different experimental methods. In the probe-recognition study, Millis and Just (1994) presented the probes only at two points in the text, making it impossible to capture the effects that occur at other positions. Meanwhile, the probe-recognition task may probably disrupt the natural reading process, leading to invalid data. It would be difficult to generalize the results to the natural reading process.

A second controversy concerns the influence of connectives on text representation. As discussed earlier, on the one hand, some results show that linguistic marking of coherence relations improves mental text representation. For instance, Degand and Sanders (2002) found that texts with causal connectives and signaling phrases led to a better comprehension performance than identical texts without these markers. In the off-line experiment, all texts were based on original encyclopedic or popular scientific articles. Topics were selected in such a way that readers were not expected to have any background knowledge about them. Four short-answer questions were designed after each text: Two tapped the causal relations while the other two focused on other parts of the texts. Results showed that the presence of linguistic markers led to a better performance to both types of the questions, suggesting that linguistic markers contributed to a more integrated mental representation of the text. On the other hand, there are a number of studies indicating that linguistic markers do not affect text representation. For example, Sanders and Noordman (2000) found that explicit marking of the relations resulted in faster processing but did not affect recall. The experiment investigated the role of causal and additive signaling phrases in newspaper expository texts. It was found that causal signaling phrases led to shorter verification latencies, but did not affect the number of correct verifications. Additive signaling phrases did not appear to influence either the verification latency or accuracy. In the free recall task, results showed that signaling phrases did not improve the quantity or quality of the information reproduced. Based on these off-line results together with the on-line results that explicit marking of relations led to faster reading time, the authors concluded that relational markers do have an effect during online processing, but their influence decreases over time.

It has been proposed in the literature that the effect of coherence marking on text comprehension depends on reader's prior knowledge of the text content in the informative texts (McNamara & Kintsch 1996; Kamalski, Sanders, & Lentz 2008). In Kamalski et al (2008), for instance, it was found in the sorting task (in which readers were asked to categorize key concepts from a text according to the text) that coherence marking interacts with prior knowledge: Low knowledge readers benefited from explicit texts, whereas high knowledge readers performed better after having read implicit texts. Accordingly, the difference between the findings in Sanders & Noordman (2000) and Degand & Sanders (2002) might be attributed to the difference in terms of the availability of world knowledge. In the former study, the texts were adapted from news paper articles, so the content information in these texts was closely related to the social life of the readers. Thus, readers were expected to have some background knowledge about them. In the latter case, however, the texts were original encyclopedic or popular scientific articles and were selected to avoid specific prior knowledge as much as possible. As a result, readers were not expected to have any background knowledge concerning these texts. As already stated in the introduction, the coherence relation is achieved both by the text and by the reader's knowledge. On the one hand, the relations are expressed by all kinds of linguistic markers such as connectives and signaling phrases. On the other hand, concepts in the text may activate world knowledge on the basis of which relations between sentences could be computed. Possibly, when world knowledge is not available for the less familiar texts such as those in Degand & Sanders (2002), readers will have to rely more on the meaning of the linguistic markers to compute and establish the coherence in the representation. In other words, readers will benefit from the linguistic marking, so that explicitly marked texts should be represented better, or more coherently, than implicitly marked texts when readers do not have the world knowledge concerning the texts. However, in the case of the texts in Sanders and Noordman (2000) which were not constructed to avoid world knowledge, readers could compute the coherence relation on the basis of their knowledge, even when the connective was absent. That is, when world knowledge is available, implicitly marked texts are probably represented as well as the explicitly marked texts.

For this matter, the present study aims to investigate the role of linguistic markers in representing simple narrative texts, in which readers are expected to have sufficient world knowledge concerning the topics. Also, the present study aims to discriminate the *delayed-integration model* and the *incremental integration model* which concerns the role of linguistic markers in the on-line reading process.

1.3. The interaction between coherence relations and connective

As a statistical concept, an interaction refers to how the effect of one factor is modulated by the effect of another factor. It seems to be a neglected issue in the literature how the effect of coherence relation is modulated by the effect of connective, or vice versa, during the reading process, and how the on-line interaction (if any) is reflected in the cognitive text representation. A few previous studies, such as Sanders and Noordman (2000), combined the investigation of *connective* and *relation* into one experiment and found main effects of the two factors separately. However, these studies did not report any interaction effect between the two factors. Moreover, these experiments restricted their study to the cases in which connectives and relations are perfectly matched with each other, and did not investigate the mismatched cases.

Little empirical work was done to investigate how linguistic markers and coherence relations interact when mismatched. Here "mismatch" refers to the incompatibility between *relation* and *connective* on the basis of world knowledge. Millis, Graesser, and Haberlandt (1993) appeared to touch upon the mismatched cases in their Experiment 3a, by comparing the reading times and performances on recall across the connective-appropriate (i.e when connectives match relations) and the connective-inappropriate (i.e when connectives mismatch relations) conditions. However, this experiment merely studied the effect of *connective* on text comprehension, either the effect of appropriate connectives or the effect of inappropriate connectives. It did not manipulate the factor of *relation*, and thus did not investigate how the effect of *relation* was modulated by the effect of *connective*, or vice versa (i.e. the interaction effect).

In sum, most of previous studies only observed main effects of *connective* and *relation* separately, whereas the interaction effect between *connective* and *relation* has rarely been reported so far. Moreover, little empirical work studied the mismatched cases or examined the interaction effect in the mismatched cases. Based on these concerns, this study aims at examining both the matched and mismatched cases and exploring how the effect of *relation* interacts with the effect of *connective* during the processing of simple narrative texts, in which readers are expected to have sufficient prior knowledge. Meanwhile, we may examine how the interaction (if any) is reflected in the final text representation through a verification task.

2. Research questions and predictions

An eye-tracking experiment was designed and conducted with simple narrative materials to investigate the controversial issues discussed before concerning the cognitive status of the coherence relation, namely, the effect of *relation* on text processing, the effect of connective on the mental representation, and the interaction between *relation* and *connective* in text comprehension. To be precise, the primary goal of this experiment was to testify the processing advantages of causal relations and meanwhile to discriminate two major theoretical proposals associated with the processing of causal relations — the *causality-by-default hypothesis* and the *causal complexity hypothesis*. The second goal of this experiment was to clarify the unsettled issues concerning the role of connectives in discourse interpretation. On the one hand, I aim to study the time course of the integration process and thus to distinguish the two integration models — the *delayed integration model* and the *incremental integration model*. On the other hand, I aim to test whether the connective can affect the final representation that readers have built after reading. The third goal was to explore the neglected question of how the connective interacts with the coherence relation during the reading process, either when there is a perfect match or a mismatch between the connective and the coherence relation that is computed on the basis of the text information and world knowledge. We will see whether the interaction is reflected in both the on-line reading process and the final representation of the text, or whether the interaction only facilitates/disrupts the on-line processing, or the interaction only affects the final representation. In the following, I will discuss how the experiment investigates these issues and what kinds of predictions were expected from the experiment.

2.1. The connective-implicit conditions and predictions

For the first purpose of the study, I decided to compare the processing of the causal-implicit relation (i.e. a causal relation without connectives) with the processing of the temporal-implicit relation (i.e. the temporal relation without connectives) in simple narrative texts for two reasons. First, in such materials, it was much easier to control textual variables across the different conditions. See (8).

(8)

Causal condition

Nina and Jacob do not live in those student apartments anymore ever since they got married. They made a lot of money all over the world. They bought a capital villa in Monaco. The villa was furnished tastefully with paintings and antiques.

Temporal condition

Nina and Jacob do not live in those student apartments anymore ever since they got married. They did a lot of travelling all over the world. They bought a capital villa in Monaco. The villa was furnished tastefully with paintings and antiques.

Across the two conditions every word is exactly the same except for two words in the verbal phrase in the second sentence (i.e. *made a lot of money* vs. *did a lot of travelling*), which subtly and naturally altered the coherence relations between temporal and causal. When the experimental materials are constructed in such a manner, the textual variance is reduced to the minimum degree and simultaneously the segments relatedness is maintained natural. On the basis of such maximally identical materials, the processing differences (if any) between the causal and temporal conditions should reflect the influence of the coherence relation on text comprehension.

Second, the comparison between temporal and causal relations may serve to distinguish the *causality-by-default hypothesis* from the *causal complexity hypothesis*. Both hypotheses apply to the comparison between temporal and causal relations, and make distinct predictions concerning the processing difference. Like the additive relation, the temporal relation is considered to be less complex than the causal one. The latter presupposes the former. Only when the relevant events can be ordered in time, subsequently, the first event, which precedes the second, can be the cause of the second (Sanders, 2005). Several acquisition studies corroborate this causal complexity idea. Temporal relations and connectives are acquired earlier than causal relations and connectives (Evers-Vermeul & Sanders 2009). Therefore, the *causal complexity hypothesis* and the *causality-by-default hypothesis* would make distinct predictions about the processing of these relations. The former hypothesis considers the causal relation as cognitively more complex and thus predicts that causal relations will be processed more slowly than temporal relations. The essence of the prediction is that the less complex temporal relation is constructed first, because less cognitive effort is involved. To further establish the causal relation on the basis of the temporal one would require more processing time. By contrast, the latter hypothesis predicts that causal relations will be processed faster than temporal relations because they are cognitively preferable. The essence of this prediction is that the reader starts out by trying to relate sentences causally and only arrives at the temporal relation when no causal relation can be established. In sum, based on these materials, we may expect to examine the effect of *relation* and distinguish the *causality-by-default hypothesis* from the *causal complexity hypothesis* by examining whether there are any reading time differences between the causal and the temporal texts and in which direction.

Meanwhile, the comparison between the processing of causal implicit texts and temporal implicit texts may shed some light on the second goal of this study — to discriminate the *delayed-integration model* and the *incremental integration model*. Millis and Just (1994) proposed the *connective integration model* while discussing the integration role of connectives, and did not specify whether readers would integrate the sentences when there are no connectives. If readers integrate the sentences on the basis of world knowledge even when there is no connective — which is very plausible concerning the idea that to comprehend text successfully readers have to construct an integrated mental representation of the text, then the implicit causal and temporal conditions can be compared to investigate the integration process. Since the causal relation is constructed during the integration process (Noordman and Vonk, 1997, 1998; Mulder, 2008), the time course of the integration determines when the above predicted effects of *relation* should appear. Conversely, the time at which the effect of *relation* occurs would reflect when readers begin the integration process. If any processing advantages or disadvantages associated with the nature of *relation* emerge well before the end of the second sentence, we will assume that readers incrementally compute the relation, integrate the sentences, and do not wait until the end of the sentence, in support of the *incremental integration model* (Traxler, Bybee, and Pickering, 1997). Otherwise, if the effects of *relation* do not occur until the end of the second sentence, it is very likely that readers set the representation of the first sentence aside in working memory as they construct a representation of the second sentence, and they do not compute the relation and integrate representations until the second sentence is fully represented, in support of the *delayed integration model* (Millis and Just, 1994).To conclude, the exact timing of the predicted effect of *relation* can provide a window on the question of where and when readers begin to integrate the sentences into a coherent representation.

2.2. The *toen* conditions and predictions

Apart from the implicit conditions, I decided to compare versions of the text with the connective *toen* (the Dutch counterpart of *then*; for the *toen* versions, see example [9] in Section 3.1). The connective *toen* may increase the overall connectedness of the experimental texts, especially the temporal texts. More importantly, since *toen* allows for a temporal relation as well as a causal relation (in which case we are dealing with underspecification), we may make use of its ambiguity to distinguish the *causality-by-default hypothesis* from the *causal complexity hypothesis*. Two kinds of predictions are possible depending on how people would like to interpret *toen* during the reading process. One possibility is that the temporal-*toen* texts will be processed faster than the causal-*toen* texts. When readers encounter *toen*, they might at first relate the sentences in a temporal sequence relation, because the temporal relation is cognitively less complex than the causal relation, in accordance with the *causal complexity hypothesis*. To further construct a causal relation on the basis of the temporality is highly likely to require more cognitive efforts, and thus more processing time. The other possibility is predicted by the *causality-by-default hypothesis*. If the *causality-by-default hypothesis* is true, then the causal preference may drive readers to interpret *toen* causally. Subsequently, they will try to integrate the conjoined segments in a causal relation. The temporal relation will be established only when readers find causality is impossible. In this case, the causal-*toen* condition should be read faster than the temporal-*toen* condition.

The *toen* conditions would serve the second goal of the study as well — the time course of the integration process. As discussed in Section 1.2, the integration process proceeds simultaneously with the construction of the relation. Therefore, whatever relations are processed faster in the *toen* texts, either the causal one or the temporal one, the time course of the effect of *relation* should reflect the time course of the integration process, just as in the implicit conditions. If the effect of *relation* occurs only at the end of the second sentence, then readers probably integrate the representations into a coherence relation only at the end of the second sentence, in line with the *delayed-integration model.* If the effect of relation appears before the end of the second sentence, readers probably build the *relation* and integrate the representations incrementally, in line with the *incremental integration model*.

Moreover, since *toen* allows for a temporal relation as well as a causal one, we may assume that there is a perfect match between *connective* and *relation* both in the causal-*toen* condition and in the temporal-*toen* condition. Thus, the *toen* conditions can be used to explore the third goal of this study: How does the effect of *relation* interact with the effect of *connective* when the two factors are matched with each other in the text? Previous studies rarely reported any of such interaction effect. However, as advocated by many previous studies (Millis and Just 1994; Cozijn, 2000), readers attempt to integrate the clauses in a fashion denoted by the meaning of the connective. In this case, it is conceivable that when matched with each other, a connective and a relation will interact to facilitate the processing of the subsequent text information. That is, the processing difference between causal relations and temporal relations should be modulated, and actually reduced by the 'cueing' effect of the connective *toen*. Therefore, we may predict that the size of the processing difference between the causal-*toen* and temporal-*toen* conditions (if any) should be smaller than the size of the processing difference between the causal implicit and temporal implicit conditions (if any). If otherwise (i.e. when the size of processing difference is relatively the same), then we have to conclude that coherence relations do not interact with matched connectives during the reading process.

2.3. The *dus* conditions and predictions

A third condition was created by inserting the Dutch connective *dus* (the Dutch counterpart of *so*; for the *dus* versions, see example [9] in Section 3.1) in the afore-discussed causal and temporal implicit versions of the text. As discussed above, readers attempt to integrate the clauses in a fashion denoted by the meaning of the connective. A crucial question concerns what happens if the meaning of the connective does not match the coherence relation computed on the basis of text content and world knowledge. This precisely concerns the third goal of this study: How does the effect of relation interact with the effect of a mismatched connective during text processing? If readers blindly follow the meaning of the connective during processing without checking it against the actual relation in the text, then no interaction between *connective* and *relation* is expected[3]. In this case, actually no processing difference should be observed

[3] Given the consistent empirical finding that connectives function as processing instructions, it is not likely that readers would neglect the connective and blindly follow the relation during processing, so we will not discuss the prediction on the basis of this possibility.

between the causal-*dus* and the temporal-*dus* conditions. Otherwise, if the processing of a connective involves making a match between the relational meaning of the connective and the actual coherence relation allowed by world knowledge, then the effect of *connective* and *relation* are expected to interact with each other: The interaction between mismatched *connective* and *relation* (i.e. the temporal-*dus* condition) should disrupt the on-line reading process, whereas the interaction between matched *connective* and *relation* (i.e. the causal-*dus* condition) should facilitate the on-line processing. That is, the effect of *relation* on discourse processing should be enlarged by the effect of a mismatched connective, and should be reduced by the effect of a matched connective. Accordingly, the size of processing difference between the causal-*dus* condition and the temporal-*dus* condition should be much larger than the size of difference between the causal-implicit and the temporal-implicit condition. Moreover, since this processing effect is triggered by the interaction between *relation* and *connective*, like all other effects associated with *relation*, the timing of its occurrence should hint at the time course of the integration. If the processing delay appears earlier than the end of the sentence, then the *delayed integration model* will probably have to be discarded. If otherwise, the *incremental integration model* will possibly deserve re-consideration. If no processing delay occurs at all, then perhaps readers will just follow the instructions of the connective in integrating the sentences, and will not check the meaning of the connective with the actual relation existing in the text during the reading process. The next question concerns how the interaction of *connective* and *relation* (if any) is reflected in the final text representation, and will be discussed in detail in the next section where we will consider relevant predictions on the basis of a verification task.

2.4 The verification task and predictions

Besides the integration process, our second goal of the present study concerns the influence of connectives on the representation of simple narratives. For this purpose, a verification task was given immediately after each text. Verification statements were designed to tap the causal relation that holds between the segments. In (8), for instance, the verification statement would be: *Nina and Jacob can afford the capital villa because they earned a lot of money all over the world.* So we expect a *yes* answer to all the causal texts and a *no* answer to all the temporal texts. The reasoning seems to be straightforward. If the connective improves text representation as suggested by many previous studies, we may predict that the connective-explicit conditions will be verified faster and more accurately than the corresponding connective-implicit conditions. If the connective interferes with text representation as suggested by Millis, Graesser & Haberlandt (1993), we may predict that the connective-implicit conditions will be verified faster and more accurately than the corresponding connective-explicit conditions. If the connective does not affect the text representation at all, then no verification performance differences, at least in terms of accuracy, will be expected between the explicit and implicit conditions. It could be proposed that connectives might facilitate the memory retrieval processes. In that case, we might expect the explicit versions to be verified faster.

As discussed before, we may predict an interaction between a relation and a matched/mismatched connective. The predicted interaction between matched *connective* and *relation* is likely to facilitate the subsequent reading process, whereas the interaction between mismatched *connective* and *relation* would probably lead to a processing delay. But how is the interaction reflected in the mental representation? The classical findings in the previous studies suggest that causally related information is represented better than non-causally related information. In this case, would the representational difference between the causal and the temporal relations be modulated, (or more precisely) reduced by the effect of a matched connective; or would the representational difference between the causal and temporal relations be enlarged by the effect of a mismatched connective? The verification task was used to examine these possibilities. If connectives do not have an effect on text representation, then there should not be any interaction effect on text representation, either. If the connective affects the final representation, but its effect does not interact with the effect of relation, then no interaction effect should be observed in the verification task. That is, the performance difference (in terms of verification accuracy and latency) between the causal and temporal relations should not be modulated by the effect of connective. If *connective* and *relation* do interact with each other to affect the final text representation, we may observe an interaction effect on the verification performance. Furthermore, if the interaction between matched *connective* and *relation* reduces the performance difference triggered by the effect of *relation*, and the interaction between mismatched *connective* and *relation* enlarges that difference, then the performance difference in verification between the causal and temporal relations should increase in the following pattern: toen < implicit < dus. Note that the verification task contributes to another purpose as well. It may force participants to read the texts carefully for comprehension so as to guarantee the validity of the reading time data obtained from the eye trackers. It should be ensured that the various reading time results are based on comprehension, not on absent-minded scanning.

2.5. Intermediate summary

Summarizing, the above-discussed hypotheses and their respective predictions are given in the following. Prediction 1, 2 and 3 concern the on-line text processing, whereas Prediction 4 and 5 concern the final text representation. On the basis of investigating these predictions in an experiment, we hope to finally clarify the role of relation, connective, and their interaction in text comprehension.

Prediction 1:

(a) According to the *causality-by-default hypothesis*, the causally related texts should be read faster than their temporally related counterparts, whether the connective is implicit or the underspecified *toen*.

(b) According to the *causal complexity hypothesis*, the temporally related texts should be read faster than their causally related counterparts, whether the connective is implicit or the underspecified *toen*.[4]

Prediction 2:

(a) If the effect of *relation* (if any) is modulated by the effect of *connective*: reduced by a matched connective and enlarged by a mismatched connective, then the size of the processing difference between the causal and the temporal relations should be ranked in

[4] Whether the causal-*dus* condition is processed faster than the temporal-dus condition depends on whether mismatched connective and relation interact with each other during the processing. For instance, if readers blindly follow the instruction of the connective *dus* without checking it with the actual relation in the text, then probably no processing difference should be observed between the two conditions.

the following increasing order: toen < implicit < dus.

(b) If *connective* and *relation* do not interact to affect the on-line processing, then no interaction effect should be observed in the reading task.

Prediction 3: Given that the coherence relation is constructed during the integration process.

(a) According to the *delayed integration model*, the predicted effects of relation or interaction in 1 and 2 should emerge at the end of the second sentence.

(b) According to the *incremental integration model*, these predicted effects of relation or interaction should appear before the end of the second sentence.

Prediction 4:

(a) If connectives affect (either improve or damage) the mental representation of the text, then the explicit version of a text should be verified differently from the implicit version of an identical text.

(b) If connectives do not affect the mental representation of the text, then no performance differences, at least in terms of response accuracy, are expected in the verification task across the implicit and the corresponding explicit versions.

Prediction 5:

(a) If the interaction between matched *connective* and *relation* reduces the verification difference triggered by the effect of *relation*, and the interaction between mismatched *connective* and *relation* enlarges that difference, then the size of verification difference between the causal and temporal relation should increase in the following pattern: toen < implicit < dus.

(b) If there is no interaction effect on the mental representation of the text, then no interaction effect should be observed in the verification task.

3. Experiment

3.1. Method

Participants

Forty-four participants were recruited from the Utrecht University community (7 male, 37 female, mean age 24). They were paid for their participation.

Materials

All the experimental texts were in Dutch. As discussed before, I aimed at constructing causal and temporal texts with minimal differences in between. First of all, we thought of 48 simple narrative and /or daily life situations which allow a natural sequence of actions to occur, such as one-day experience of a young woman: working all day long, going to see her parents after work, returning to her own home, and going to bed, etc. Second, we chose 2 or 3 sequential actions in such situations to construct the temporally related stories. Thirdly, we created an alternative causal link in the series of actions so as to make the causal version of the story. Often, this manipulation between causal and temporal relations was achieved by altering the main verb or the verbal phrase of the pre-target sentence. The target sentences were kept identical across the conditions. Fourthly, we added to each version of the story an identical first sentence to describe the background and an identical final sentence to make the context richer and more meaningful. After that, we arrived at 96 (i.e. 48 situations × 2 relations) short narrative stories. Finally, we added the connectives — either the connective *dus* or the connective *toen* or no connective at all — to these stories, obtaining the final set of 288 (i.e. 48 situations × 2 relations × 3 connectives) experimental texts. Please see the six versions of an example story in Example (9). The naturalness of the materials was checked by a team of discourse researchers, who criticized and revised the materials in different stages of the text construction process.

(9)

Causal-*dus*

Gisteren werkte Daphne de hele dag in het restaurant. Daarna ging ze naar haar ouders. Ze kwam om 10 uur 's avonds thuis en voelde zich uitgeput. Dus ging ze meteen naar bed. Ze sliep die nacht heerlijk.

(Yesterday, Daphne worked all day long at the restaurant. After that, she went to see her parents. She arrived at home around 10, feeling exhausted. So she went to bed right away. She had a very sound sleep that night.)

Temporal-*dus*

Gisteren werkte Daphne de hele dag in het restaurant. Daarna ging ze naar haar ouders. Ze kwam om 10 uur 's avonds thuis en voelde zich gelukkig. Dus ging ze meteen naar bed. Ze sliep die nacht heerlijk.

(Yesterday, Daphne worked all day long at the restaurant. After that, she went to see her parents. She arrived at home around 10, feeling happy. So she went to bed right away. She had a very sound sleep that night.)

Causal- *toen*

Gisteren werkte Daphne de hele dag in het restaurant. Daarna ging ze naar haar ouders. Ze kwam om 10 uur 's avonds thuis en voelde zich uitgeput. Toen ging ze meteen naar bed. Ze sliep die nacht heerlijk.

(Yesterday, Daphne worked all day long at the restaurant. After that, she went to see her parents. She arrived at home around 10, feeling exhausted. Then she went to bed right away. She had a very sound sleep that night.)

Temporal-*toen*

Gisteren werkte Daphne de hele dag in het restaurant. Daarna ging ze naar haar ouders. Ze kwam om 10 uur 's avonds thuis en voelde zich gelukkig. Toen ging ze meteen naar bed. Ze sliep die nacht heerlijk.

(Yesterday, Daphne worked all day long at the restaurant. After that, she went to see her parents. She arrived at home around 10, feeling happy. Then she went to bed right away. She had a very sound sleep that night.)

Causal-implicit

Gisteren werkte Daphne de hele dag in het restaurant. Daarna ging ze naar haar ouders. Ze kwam om 10 uur 's avonds thuis en voelde zich uitgeput. Ze ging meteen naar bed. Ze sliep die nacht heerlijk..

(Yesterday, Daphne worked all day long at the restaurant. After that, she went to see her parents. She arrived at home around 10, feeling exhausted. She went to bed right away. She had a very sound sleep that night.)

Temporal-implicit

Gisteren werkte Daphne de hele dag in het restaurant. Daarna ging ze naar haar ouders. Ze kwam om 10 uur 's avonds thuis en voelde zich gelukkig. Ze ging meteen naar bed. Ze sliep die nacht heerlijk.

(Yesterday, Daphne worked all day long at the restaurant. After that, she went to see her parents. She arrived at home around 10, feeling happy. She went to bed right away. She had a very sound sleep that night.)

Verification: *Daphne ging meteen naar bed toen ze thuis kwam omdat ze uitgeput was.*

(Daphne went to bed when she arrived at home because she felt too exhausted to do anything else)

In the manipulations, we took great care to control across temporal texts and causal texts for the degree of semantic priming, content expectation, or schematic structural expectation created by the context. The *schematic structural expectation hypothesis* is teased apart from the *causality-by-default hypothesis* and the *causal complexity hypothesis* in the present experiment because the narrative experimental texts were constructed in such a way that the cause-consequence condition and the temporal condition are not expected to be different in terms of structural expectation. Both of them follow the same narrative structure. Each text begins with a background description, followed by a sequence of events taking place against this background.

The stimuli were divided into 6 lists. Each list contained all the 48 daily life situations (we may call them basic stories) and all the 6 experimental conditions, with only one version of each basic story within each list (hence 48 test items in total within each list). Thus, each basic story occurred in a different version in different lists. Apart from the test items, there were 48 fillers in each list. Thus, each list contained 96 texts: 48 test texts and 48 filler texts. The texts within each list, including the test items and fillers, were pseudo-randomly divided into 5 blocks. This pseudo-randomization was used to ensure that the six experimental conditions were distributed over the blocks in a balanced way. Only one pseudo-randomized order was used per list. Forty-eight verification statements were constructed to be attached to the test items, which were logical inferences or conclusions that could be drawn from the causal texts. The other set of 48 verification statements were created for the filler items. The verification statement was identical across the conditions.

Note that to prevent an 'edge effect'[5] in the processing time measures, the stimuli were designed in such a way that the regions that were critical to our analysis were displayed near the centre of the screen.

Procedure

Each session started with a written instruction, informing participants of the experimental procedure and the points for attention. After the instruction, the headset was mounted onto the head of the participant, and the cameras on the headset were adjusted and calibrated. During the calibration procedure the participants had to fixate on a random sequence of dots at various locations on the screen. The calibration

[5] It is well-acknowledged that the reading times associated with line beginnings and endings are likely to be contaminated by return sweeps. The first and last fixations on a line are generally 5-7 letter spaces from the ends of a line (Rayner 1998: 375). The first fixation on a line tends to be longer than other fixations, and the last is shorter (375). We call this type of effects the 'edge effect'.

procedure and a subsequent validation of the calibration result were carried out at the beginning of each block. Upon successful calibration and validation, the experiment started with 3 practice items. Before the presentation, a fixation point appeared on the screen at the position of the incoming first word of the text. The participant had to look at the fixation point to make the text available. After reading each text, the participant needed to press the middle button on the response box to make the verification statement appear. In response to it, readers had to press either the left button (standing for yes) or the right button (standing for no) on the response box, according to the judgment about whether the statement was a logical inference or conclusion on the basis of the text information. In this manner, the practice items were used to familiarize the participant with the basic procedures of each trial, after which the experiment proceeded from block 1 till the end of block 5. Each participant read 96 texts in the experiment, which took 40 minutes on the average excluding instruction and camera adjustment.

The test order was automatically selected by the computer based on the subject number. The first subject got the first list, the second subject got the second list, the seventh subject got the first list again, and so on.

Analysis

Prior to analysis, I deleted 4.4% of the data in Fixation because of frequent eye blinks, reported headache, program crashes, and accidental missing data. Furthermore, any processing measures more than 2 standard deviations from both the *participant's mean* and the *item's mean* were treated as missing data. In addition, any measures of the regions containing blinks were also treated as missing data.

Each experimental text was divided into 6 regions. Region 1 is the context before the target sentence. The target sentence is the pre-final sentence, and contains the 2nd till the 4th region. Region 5 is right after the target sentence and contains the last few words of the target line. Region 6 is the last line of the text. See Example (11):

(11)

Gisteren werkte Daphne de hele dag in het restaurant. Daarna
ging ze naar haar ouders. Ze kwam om 10 uur 's avonds thuis en
voelde zich uitgeput./ Dus ging ze/ meteen/ naar bed./ Ze sliep die/
nacht heerlijk.
(Yesterday worked Daphne the whole day at the restaurant. Afterwards
went she to her parents. She came at 10 o'clock in the evening at home and
felt exhausted./ So went she/ right away/to bed./ She slept that/
night soundly.)

Region 2 till 6 was the target of our analysis. For each of these 5 regions, I will report mean reading times and the result of the *linear mixed effects regressions* analysis. Three different first-pass eye movement measures will be adopted in our discussion. *First-fixation duration* (abbreviated as FF) reflects the duration of the first fixation within a given region. *First- pass reading time* (abbreviated as FP) is the total reading time spent on a region before the eyes leave the region either in a progressive manner or a regressive manner. Finally, *regression path duration* (abbreviated as RP) is the sum of fixations and saccade durations from the time when the eyes enter a region to the time when the eyes progressively enter the next region. As implicated by the definitions, the three measures allow processes that occur somewhat later to enter the computation. *First- pass reading times* consist of first fixation durations plus additional successive fixations within the region that directly follow the first fixation. *Regression path duration* incorporates the *first- pass reading time*, as well as the duration of the regression (if present).

3.2. Reading time results and discussion

The experiment was a typical repeated measures design, with two within-subject factors: *relation* (2 levels: causal vs. temporal) and *connective* (3 levels: dus vs. toen vs. implicit). A *linear mixed effects regression* analysis was carried out on the log of the reading times to search for any significant main effects, or interaction effect of the two factors. The results are shown in Table 1, which displays the mean *first fixation duration*, *first-pass reading time*, and *regression path duration* spent in each target region.

At Region 2, the beginning region in the target sentence, there was a significant interaction effect in *first fixation duration* (χ^2 [2] = 7.880; p= 0.019). The causal-*toen* condition was read significantly faster than the temporal-*toen* condition (χ^2[1] = 4.897; p= 0.027), while no reading time differences were found between the causal-*dus* and the temporal dus conditions (χ^2 [1] = 0.181; p= 0.670), or between the causal-implicit and the temporal-implicit conditions (χ^2 [1] = 3.200; p= 0.074). Another interaction effect was found in *first pass reading time* (χ^2 [2] = 6.177; p = 0.046). The causal-*dus* condition was read faster than the temporal-*dus* condition (χ^2[1] = 8.190; p= 0.004), whereas no significant differences were found between the causal-*toen* and the temporal-*toen* conditions (χ^2 [1] =0.647; p= 0.421), or between the causal-implicit and the temporal-implicit conditions (χ^2 [1] = 1.582; p= 0.209). In sum, according to the three reading time measures, effects of *relation* were found only in the connective-explicit texts, in which the causal relations were read significantly faster than the temporal relations. No significant effect of relation were observed between the implicit conditions (FF: χ^2 [1] = 3.200; p= 0.074; FP: χ^2[1] = 1.582; p= 0.209; RP: χ^2 [1] = 3.031; p= 0.082).

Apart from the interaction effects, a main effect of *connective* was found in this region in *regression path duration* (χ^2 [2] = 59.346; p < 0.000). The explicit conditions were read significantly more slowly than the implicit conditions (i.e. dus > imp: χ^2 [1] = 31.623, p< 0.000; toen > imp: χ^2 [1] = 53.624; p < 0.000), which should be no surprise because the connective conditions contain one more word (i.e. the connective) than the implicit conditions. No processing difference was observed between the explicit *toen* and *dus* conditions (χ^2 [1] = 2.004; p= 0.157).

The observed processing advantage of causal-*toen* texts over temporal-*toen* texts conforms to Prediction 1(a), and thus strongly supports the *causality-by-default hypothesis*. Readers started out by interpreting *toen* causally and tried to construct a causal relation accordingly, so that the causally related texts were read faster than the temporally related texts. Moreover, the fact that no processing difference was observed between the *toen* and *dus* conditions is in favor of the *causality-by-default hypothesis* as well: Readers processed the causal connective *dus* and the underspecified connective *toen* in a similar way, because they interpreted *toen* as a causal connective in the first place out of a causal preference. Next, the observed interaction effects in FF and FP suggest that the effect of relation on discourse processing was modulated by the effect of *connective*. Probably it has to do with the integration function of connectives. I will discuss about it in detail in Section 4.2. Besides, the findings about the early emergence of the effect of relation in the explicit texts are in line with Prediction 3(b) and thus advocate the *incremental integration model.* When there was a connective, readers began to compute the relation and integrate the segments at the beginning of the second sentence. When there was no connective, no effect of *relation* was observed at this early region. Possibly in the implicit conditions the reader would integrate the segments at a different time, perhaps at the end of the sentence, in line with the delayed-integration model.

Table 1. Result of *linear mixed effects regression* analysis in terms of *the first fixation duration, the first pass reading time, and the regression path duration* (in ms)

	Region **2**	Region **3**	Region **4**	Region **5**	Region **6**
Dutch item:	*Dus/Toen* ging ze or Ze ging	*meteen*	*naar bed.*	*Ze sliep die*	*nacht heerlijk.*
Translation:	*So/Then* went she or She went	right away	to bed.	She slept that	night soundly.
Mean reading time of the *first fixation duration*:					
cau- dus	199	194	205	195	190
tem-dus	202	205	219	213	193
cau-toen	195	199	211	194	191
tem-toen	205	201	214	196	194
cau-imp	218	199	207	200	194
tem-imp	203	206	220	206	200
Mean reading time of the *first pass duration*:					
cau- dus	301	349	384	295	1021
tem-dus	344	380	437	310	998
cau-toen	351	350	394	279	1067
tem-toen	356	368	444	284	1070
cau-imp	298	359	389	295	1083
tem-imp	274	381	426	303	1086
Mean reading time of the *regression path duration*:					
cau- dus	411	448	513	344	1740
tem-dus	448	570	836	489	2382
cau-toen	450	439	580	407	2106
tem-toen	467	498	625	370	2113
cau-imp	393	469	478	304	1794
tem-imp	353	478	590	378	2085

At Region 3, the middle region in the target sentence, there was a significant main effect of *relation* in the first pass reading time (χ^2 [1] = 4.250; p= 0.040): On the whole, the causal relations were read faster than the temporal relations. In the regression path duration, there was also a main effect of *relation* (χ^2 [1] = 12.914; p= 0.000), but this main effect was modulated by an interaction (χ^2 [2] = 6.117; p= 0.047): The temporal relation led to longer regression path duration than the causal relation only when *dus* was present (i.e. causal-*dus* <temporal-*dus*, χ^2[1] = 17.152; p < 0.000). No processing difference in terms of RP was found when *toen* was used (i.e. causal-*toen* = temporal-*toen*, χ^2 [1] = 1.346, p= 0.246) or when no connective was present (i.e. causal-implicit = temporal-implicit, χ^2 [1] = 0.948; p= 0.330).

The most important finding in this region is the emergence of the effect of *relation* in the implicit conditions. Firstly, it is in line with Prediction 1(a) and thus supports the *causality-by-default hypothesis*. Although the causal relation appears to be cognitively more complex than the temporal relation, it was processed faster because readers start out assuming the relation between two consecutive sentences is a causal relation and only arrive at the temporal relation when it is impossible to establish the causal one. Secondly, it conforms to Prediction 3(b) and thus supports the *incremental integration model.* Readers did not wait until the end of the second sentence to integrate the segments, even when there were no linguistic markers in the text. Thirdly, it suggests that the integration process is affected by the presence or absence of the connective. When there was a connective, readers began to incrementally integrate the segments at the beginning of the second sentence. When no linguistic markers were present to specify the exact relation readers did not integrate the sentences immediately. They waited until the middle of the second sentence (where more disambiguating information was available) to construct the coherence relation in the mental representation. Besides, the findings about the mismatched temporal-*dus* condition are also important. Results show that the temporal-*dus* condition requires not only more *first pass reading time* but also longer *regression path* duration to the earlier text, suggesting that it is the most difficult condition to process among the three temporal conditions. The extra difficulty should be interpreted as a result of the interaction between mismatched connective *dus* and the temporal relation, and thus objects to the idea that readers blindly follow the instructions of the connective in the integration process. Conversely, the processing of a connective involves making a match between the relational meaning of the connective and the relation computed on the basis of the content of the segments and world knowledge. Finally, the severe difficulty associated with the temporal-*dus* condition implied that it was very hard to compute a causal link in the temporal texts, and thus guaranteed the validity of the experimental materials.

At Region 4, which is the end of the target sentence, there was a significant main effect of *relation* in all of the three reading time measures: *first fixation duration* (χ^2[1] = 6.145; p= 0.013), *first pass reading time* (χ^2[1] = 23.306; p< 0.000), and *regression path duration* (χ^2[1] = 53.372; p< 0.000). Overall, the causal relations were read faster than the temporal relations. In *regression path duration*, an interaction effect was also significant (χ^2[2] = 15.116; p= 0.000), showing that the size of the difference was larger between the causal-*dus* and the temporal-*dus* conditions (i.e. 323 ms difference, χ^2 [1] = 43.664; p < 0.000) than the size of the difference between the causal-implicit and temporal-implicit conditions (i.e. 112 ms difference, χ^2[1] = 6.908, p= 0.032), and that the size of the difference between the causal-implicit and temporal-implicit conditions was larger than the size of the difference between the causal-*toen* and the temporal-*toen* conditions (i.e. 45 ms difference, χ^2 [1] = 4.210; p= 0.040).

Clearly, the observed main effect of *relation* in the middle of the sentence (i.e. Region 3) was carried on to the end of the sentence (i.e. Region 4) and was extended from *first pass reading time* to the other two processing measures, *first fixation duration* and *regression path duration.* The overall effect of relation should be interpreted as convincing evidence for the processing advantage of causality, and the *causality-by-default hypothesis*. In addition, the extremely large difference associated with the *dus* conditions (i.e. 323 ms difference in *regression pass duration*) and the smallest difference associated with the *toen* conditions (i.e. 45 ms difference in *regression pass duration*) conform to Prediction 2(a) that the size of the processing difference between the causal and the temporal relations should be ranked in the following increasing order: toen < implicit < dus. Thus the finding confirms that mismatched connective and relation interact to disrupt the on-line reading process, and that matched connective and relation interact to facilitate the subsequent reading process.

At Region 5, the end of the target line, there was a significant main effect of *relation* in the first fixation duration (χ^2 [1] = 8.081; p= 0.004), showing that the causal relations were read significantly faster than the temporal relations. In the regression path duration, however, the main effect of *relation* (χ^2 [1] = 16.852; p< 0.000) was modulated by an interaction effect (χ^2[2] = 6.953; p= 0.031). The temporal texts were read significantly slower in the *dus* condition (i.e., causal-*dus* < temporal-*dus*; χ^2 [1] = 14.009; p= 0.000) and the implicit condition (i.e., causal-implicit <temporal-implicit; χ^2 [1] = 0.948; p= 0.000). But no processing differences were found between the *toen* conditions (i.e., causal-*toen* = temporal-*toen*, χ^2 [1] = 0.031; p= 0.860). Besides, there was a main effect of *connective* in *first pass reading time* (χ^2[2] = 9.092; p= 0.011): The *toen* conditions were processed faster than the *dus* and the implicit conditions (i.e. toen < implicit, χ^2[1] = 27.471, p= 0.006; toen < dus, χ^2 [1] = 6.767; p= 0.009), while no differences were found between the *dus* and the implicit conditions (χ^2[1] = 0.068; p= 0.795).

Interestingly, the effect of *relation* disappeared in RP at Region 5 in the *toen* conditions while persisting in the *dus* and implicit conditions. Presumably, the processing difficulty associated with the temporal relation was overcome earlier in the *toen* conditions. With the help of the meaning of *toen*, readers resorted to the temporal relation right away when they found it impossible to establish the preferable causal relation in the temporal texts. By contrast, it took readers longer to arrive at the temporal relation when the connective cue was implicit. In the cases with *dus*, the misused connective did cue readers how to relate and integrate the conjoined sentences, but in an incorrect way, leading to the longer processing time as well. The above interpretation corresponds to the idea that *connective* and *relation* interact to facilitate the subsequent reading process when they are matched with each other. Moreover, the processing difficulty associated with the temporal-*dus* condition seemed to be the worst: The processing difference amounts to 145 ms in RP, twice of the processing difference between the implicit conditions (i.e 74 ms). We may take these results to suggest that mismatched *connective* and *relation* interact to disrupt the processing.

The finding that the connective *toen* led to faster processing in FP can be interpreted as the facilitating effect of an appropriate connective on the on-line processing. In addition, this result could be related to the finding that the effect of relation disappeared in RP in the toen conditions. If we interpret the latter finding as an indication that the processing difficulty associated with the temporal relation was overcome earlier in the *toen* conditions than in the *dus* and the implicit conditions, then the former finding would seem to be straightforward.

At Region 6, the final line of the text, there was a significant main effect of *relation* (χ^2 [1] = 9.977; p=0.002) in *regression path duration* and it was modulated by an interaction (χ^2 [2] = 7.30; p=0.025): The causal-*dus* condition was processed significantly faster than the temporal-*dus* condition (χ^2 [1]= 14.451; p=0.000), but no reading time differences were found between the causal-*toen* and temporal-*toen* conditions (χ^2[1] = 0.054; p= 0.817), or between the causal-implicit and temporal-implicit conditions (χ^2[1] = 1.498; p= 0.221).

Importantly, the processing difficulty associated with the temporal-*dus* condition spilled further down till the end of the text. This finding reflects that the difficulty triggered by the mismatched connective and relation disrupted the whole reading process. Readers were probably trying hard to detect a causal chain out of the temporal-*dus* texts throughout the reading process. This result again suggests that the connective and the relation interacted during reading. But the question remains how this interaction affects the final representation of the text? We may find an answer to it by examining the results from the verification task.

3.3. Response result and discussion

I removed 1.5% of the response data from analysis because of reported headache, and program crashes. Then I did a 'General Linear Model" (GLM) repeated measures analysis in SPSS to find out the proportion of correct responses in the six experimental conditions, respectively (see Table 2). No effect of *connective* was found in the *proportion correct* analysis (F1[2,42]= 1.67, p= 0.200, η^2= 0.07; F2[2,46]= 1.36, p= 0.266, η^2= 0.06). No interaction effect was observed either (F1[2,42]= 0.951, p= 0.394, η^2= 0.04; F2[2,46]= 1.11, p= 0.340, η^2= 0.05). Especially, the connective *dus*, which was taken to be a clear cue for the causal relation, did not make the response accuracy significantly different from the underspecified connective *toen*, or from the connective-implicit condition. The result conforms to Prediction 4(b) and 5(b). Thus, we may take these results to suggest that neither connectives nor the interaction between *connective* and *relation* influence the mental representation of the text.

Table 2 Result from 'General Linear Model' (GLM) repeated measures procedure on *proportion correct*, and the result from Linear mixed effects regression analysis on *response time.*

condition	proportion correct	response time (in ms)
cau-dus	.87	2391
cau-imp	.83	2615
cau-toen	.82	2639
tem-dus	.62	2975
tem-imp	.64	2830
tem-toen	.61	2916

To observe closely at the effect of a mismatched connective on text representation, a comparison was conducted among the three temporal conditions in SPSS. No significant difference was observed in terms of response accuracy (F1[2,42]= 0.535, p= 0.590, η^2= 0.025; F2[2,46]= 0.321, p= 0.727, η^2= 0.014). The temporal-*dus* condition was verified as accurately as the other two temporal conditions. This finding suggests that in the texts with mismatched connective and relation readers represent the texts according to the actual relation allowed by the world knowledge.

Besides, we found a significant effect of *relation* in both the subject analysis ($F1[1, 43]= 36.10$; $p= 0.000$; $\eta^2= 0.46$) and the item analysis ($F2[1, 47]= 21.21$; $p= 0.000$; $\eta^2= 0.31$). The proportion of correct responses was significantly higher in causal texts (i.e. 84%) than in temporal texts (i.e. 62%). This finding conforms to the frequent findings in the literature, and suggests a representational advantage of the causal relation. The causal relation is represented better so that it is verified more accurately. Alternatively, the occurrence of the effect of *relation* was perhaps a result of the design itself. As discussed in Section 2, the verification task is not designed to examine the effect of relation on text representation. Thus, I did not control for task variables across the causal and temporal relations. The verification statements always tap the causal relation in the causal texts. Consequently, we always expect 'yes' for the causal texts and 'no' for the temporal texts. It could be argued that the effect of *relation* was a result of the imbalanced 'yes/no' distribution over causal and temporal relations. Probably, it is much easier for readers to make a positive response than a negative response to the verification task.

In order to examine the *response time*, I did a *Linear mixed effects regression* analysis on the response time data (see Table 2). A significant main effect of *relation* (causal < temporal; $\chi^2 [1] = 66.468$; $p < 0.000$) and an interaction effect ($\chi^2[2] = 7.445$; $p=0.024$) were observed. All temporally related texts required significantly longer response time than their respective causal counterparts (in the *dus* versions: $\chi^2 [1] = 44.592$; $p < 0.000$; in the *toen* versions: $\chi^2 [1] = 10.627$; $p = 0.001$; in the *dus* versions: $\chi^2 [1] = 17.358$; $p < 0.000$). The size of the difference was bigger between the causal-*dus* and temporal-*dus* conditions (i.e. 584 ms difference) than between the causal-*toen* and temporal-*toen* conditions (i.e. 277 ms difference), or between the causal implicit and temporal implicit conditions (i.e. 215 ms difference). Again, this result is in line with the classical hypothesis about the representational advantage of causality. Causally related texts were verified faster, because they were represented better. However, this effect could also be attributed to the imbalanced yes/no distribution over the causal and temporal relations. Probably the temporal relations were verified more slowly because it took more time to make a negative judgment. According to the interaction analysis, the response time was significantly shorter if the connective was *dus* than if the connective was *toen* ($\chi^2[1] = 6.871$; $p=0.009$) or implicit ($\chi^2[1] = 8.798$; $p=0.016$), and this effect of connective was restricted to the causally related texts. It seems that *dus* has a facilitative effect in the verification task when it is used properly (i.e when it matches the coherence relation in the text). Given the fact that *toen* did not lead to a shorter response time as *dus* did, we may not attribute this effect to the function of a connective in general, but to some special properties of the causal connectives. Furthermore, since the finding in *proportion correct* suggests that the presence of *dus* did not lead to a different representation, it is unlikely to attribute the shorter response time to any representational advantage of *dus*. We may assume that it has to do with the representation retrieval processes. Probably causal representations with *dus* are retrieved faster, and thus were verified faster. This assumption could also explain the large difference in terms of response time between the causal-*dus* and the temporal-*dus* conditions (i.e. 584 ms difference). But we will need more studies to investigate this assumption.

4. General discussion

In this article, I investigated 3 unsettled issues in the literature concerning the cognitive status of the coherence relation, namely, the effect of *relation* on text processing, the effect of *connective* on the mental representation, and the interaction between *relation* and *connective* in discourse interpretation. Meanwhile, I tried to distinguish several theoretical hypotheses closely related to these issues, that is, the *causality-by-default hypothesis* vs. the *causal complexity hypothesis*, and the *incremental integration model* vs. the *delayed integration model.* For these goals, I conducted an eye-tracking experiment on simple narrative materials which allowed us to directly compare the causal relation with the temporal relation.

The results found in this experiment are summed up in Table 3, and will be discussed in the following subsections in accordance with the above-mentioned three unsettled issues.

Table 3 Summary of results of the experiment

reading time effect	emergence	Spill over to (in RP)	response accuracy	Response time
Cau-dus < tem-dus	Region 2 (FP)	Region 6	Dus = toen = implicit	Cau-dus < cau-toen = cau-imp
Cau-toen < tem-toen	Region 2 (FF)	Region 4	Temporal < causal	Causal < temporal
Cau-imp < tem-imp	Region 3 (FP)	Region 5		
Toen < dus = imp	Region 5 (FP)			

Note: < indicates shorter time or lower response accuracy.

4.1. The role of relation on text processing — Causality by default hypothesis and Causal complexity hypothesis

To begin with, on the ground that our text materials were optimally designed to be maximally identical across the causal and temporal relations, the observed reading time differences should reflect that the nature of relation affects on-line text processing. Moreover, the direction of the reading time differences conforms to Prediction 1(a). As clearly shown in Table 2, overall the causal relations were processed significantly faster than the temporal relations in the various reading time measures, in spite of the fact that they are semantically more complex. Therefore, the observed reading time effects should be interpreted as convincing evidence for the *causality-by-default hypothesis*, and as counterevidence for the *causal complexity hypothesis.*

In addition, we found that the causal texts were verified faster and more accurately than the temporal texts, identical to the result found in Sanders and Noordman (2000). We may interpret this finding from two perspectives. On the one hand, it is in line with proposals about the representational advantage of causal relations. Causally related texts were verified faster and more accurately because they were represented better. On the other hand, it could be a result of the design itself. As discussed before, the temporal texts required readers to make negative answers, while the causal texts required readers to make positive answers. Temporally related texts were verified more slowly and less accurately, probably because it is much more difficult for readers to make a negative response than a positive one to the verification task. In sum, because the factor of relation is confounded with the factor of yes/no distribution across the relations, no solid conclusion could be drawn about the bad verification performance in the temporal conditions.

4.2. The role of connectives — Incremental integration model and Delayed integration model

The result that effects of *relation* emerged well before the end of the target sentence conforms to Prediction 3(b) and thus implies that readers try to relate the sentences incrementally and do not wait until the end of the sentence. This finding confirms the *incremental integration model* which claims that readers incrementally combine representations of two consecutive clauses into an integrated representation, and hence refuted the *delayed integration model* that readers do not integrate the segments until the end of the sentence. It should be noted that the presence or absence of a connective seems to affect the on-line integration process. The effect of *relation* appeared late in the connective-implicit condition, when compared to the connective-explicit conditions. We are inclined to account for this late effect of *relation* by assuming a relatively late integration for the implicit conditions. Readers wanted to process more information before integrating the target sentence with the previous one when there was no connective to signal the exact coherence relation. This does not run into conflict with the *causality-by-default hypothesis*, since that hypothesis claims only that readers start out assuming the relation between two consecutive sentences is a causal relation (given certain characteristics of two discourse segments) but does not specify when readers begin to make that 'causal assumption'. Here we may draw a tentative conclusion about the integration process: On the one hand, readers would incrementally integrate the clauses, probably on a word-by-word basis, whenever there is a connective; on the other hand, when there is no connective, readers would wait until more information was available, probably conduct the integration in the middle of the sentence. Our conclusion is just in line with the claim made by Millis and Just (1994): Readers attempt to integrate the clauses in a fashion denoted by the meaning of the connective; when there is no connective, readers are not obliged to integrate the clauses in the same way as when a connective is present.

With respect to the effect of *connective* on text representation, it was found that connectives did not make the verification response significantly more or less accurate than the connective-implicit condition. The result conforms to Prediction 4(b), and thus suggests that connectives do not influence the mental representation of the text. There is a striking difference between this result and some previous findings in the literature. In particular, Degand and Sanders (2002) concluded that linguistic markers in expository texts indeed influenced the reader's representation after reading. I believe that this difference in results may be due to the factor of the reader's knowledge. In the present experiment, we expect readers to have sufficient background knowledge concerning the simple narrative experimental materials, whereas in Degand and Sanders (2002) readers were not expected to have any background knowledge about the unfamiliar encyclopedic materials. Presumably, readers rely more on the connective in the construction of the mental representation when background knowledge is not available; in contrast, they will depend more on the actual relation allowed by the content of the segments and world knowledge when they have sufficient background knowledge to check the connective against the actual relation in the text.

Although this experiment does not aim at studying the effect of *connective* on text processing, we did find a main effect of connective immediately following the target sentence. The connective *toen* led to faster processing in FP. This finding can be interpreted as the facilitating effect of an appropriate connective on the on-line processing. In addition, this result could be related to the finding at the same region that the effect of relation disappeared in RP in the toen conditions.

4.3. The interaction between coherence relation and connective

The ranking of the processing differences observed in the reading task (i.e. the size of the processing difference increases in the order: toen < implicit < dus) conforms to Prediction 2(a), and suggests that the effect of relation on text processing was modulated by the effect of connectives. Mismatched *connective* and *relation* interact to disrupt the on-line reading process, whereas matched *coherence relation* and *connective* interact to facilitate the processing of subsequent information.

Another finding, which is closely related to the interaction effect, concerns when the effect of *relation* disappeared. As clearly shown in Table 3, the effect of *relation* disappeared one after another in the following order *toen* < implicit < *dus*. The fact that the effect of *relation* disappeared the first in the *toen* condition and disappeared the last in the *dus* condition provides a window on the interaction between *relation* and *connective* during the reading process. We may assume that the disappearance of the effect of relation is an indication that the reader's processing problem associated with the temporal relations has been solved in some way, then we are able to arrive at a plausible explanation. The effect of *relation* disappeared earlier in the cases with *toen*, because the problem was solved earlier. The ambiguous *toen* gave readers two options, when the initially preferred causal interpretation was denied the temporal interpretation was easily adopted. In the implicit cases, it took readers longer time to arrive at the correct temporal relation, because no connective was present to give them a cue about it. However, in the temporal-*dus* condition, the problem could hardly be solved because of the mismatch between connective and relation, which led to a long-lasting processing difficulty. This lasting processing difficulty suggests that readers do not blindly follow the instructions of the connective in constructing a coherent representation. Instead, they keep on checking the relational meaning of the connective against the actually relation allowed by the content of the segments and world knowledge throughout the reading process. To conclude, the disappearing pattern of the effect of *relation*, together with the ranking of the processing difference, suggests that coherence relations and connectives interact with each other during the on-line processing: Their interaction facilitates the processing of subsequent information, when they are matched with each other; their interaction disrupts the processing when mismatched.

The whole previous part is about the interaction between *relation* and *connective* during the reading process. The next question concerns how the on-line interaction between *connective* and *relation* is reflected on the final text representation. The answer was found out by examining the results in the verification task. The fact that no interaction effect was observed in terms of verification accuracy suggests that the on-line interaction between *connective* and *relation* do not affect the final text representation: The representational difference across relations is not modulated by an effect of *connective*. This finding corresponds to the conclusion in Section 4.2 that connectives do not have any effect on the final text representation. Furthermore, the result that no verification differences were observed among the 3 temporal conditions suggests that in the texts with mismatched *connective* and *relation* (i.e. the temporal-*dus* condition) readers were capable of representing the texts coherently according to the actual relation allowed by the world knowledge, irrespective of the on-line disruption. In addition, we did find an interaction effect in response latency (i.e. the causal-*dus* condition was verified faster than the other conditions), but it was restricted to the causal connective *dus* in the causally related texts. No such facilitation effect was found for *dus* in the temporally related texts, or with the other connective *toen,* and no facilitation effect was observed in terms of response accuracy. Accordingly, it is unlikely to be generalized into a facilitating effect on text representation. We may assume it to be a retrieval advantage of the causal connectives. Probably causal representations with a causal connective, like *dus*, are retrieved faster, and thus were verified faster. But we will need more studies to investigate this assumption.

In conclusion, the present eye-tracking experiment confirms the *causality-by-default hypothesis* and the *incremental integration model*, as our results clearly show that the causal relation was processed faster than the temporal relation, and this effect emerged well before the end of the sentence. Besides, the verification results suggest that connectives do not influence the mental representation of the text when the reader's world knowledge allows them to compute the relation on the basis of the content of the segments. Finally, when combining the reading time and verification results, we see that matched *connective* and *relation* interacted to facilitate the reading process but did not lead to a different representation, and that the mismatch between *relation* and *connective* disrupted the on-line processing but did not lead to an incoherent mental representation. Rather, in the texts with mismatched *connective* and *relation* readers represent the texts according to the actual relation allowed by the world knowledge.

On the basis of these results together with the earlier results reported in the literature, we may further conclude that coherence relations have cognitive relevance. Coherence relations influence both discourse processing and discourse representation. Moreover, linguistic markers of coherence relations function as processing instructions, but do not affect the final representation of the text, at least when readers have sufficient world knowledge concerning the texts. Finally, coherence relations and linguistic markers are independent coherence variables, they interact with each other during the processing. However, the on-line interaction does not affect the mental text representation.

5. Future studies

This study certainly has its limitations. One major issue concerns the verification task. As discussed in Section 2.4, the verification statements were designed to tap the causal relation that holds between the segments. In (8), for instance, the verification statement would be: *Nina and Jacob can afford the capital villa because they earned a lot of money all over the world.* It could be argued that the verification task of the experiment may encourage the participants to relate events causally, and thus the observed processing advantage of causal relations would be in part due to the nature of the verification task. This concern has pointed to the need for replications in future to guarantee that the observed tendency to relate events or states causally was not a task-driven processing strategy, but a spontaneous, automatic cognitive process. Another issue is that in this article I have confined the investigation to simple narrative materials for which readers were expected to have sufficient world knowledge. Further progress can be achieved by extending the investigation to other text genres such as expository and persuasive texts.

Some results of this study also give rise to new questions for future studies. One comes from the finding that the causal connective *dus* led to faster verification of the causally related texts, and suggests that causal connectives, such as *dus*, facilitate the retrieval process of text representations from memory (when properly used in the causally related texts). Another inspiring finding is that the effect of *relation* emerged earlier in the connective-explicit conditions than in the connective-implicit condition, and suggests that the time course of integration is affected by the presence or the absence of a connective. We expect these suggestions to be stimulating for future studies in text processing and representation.

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References

Asher, N. & Lascarides, A. (1998). Bridging. *Journal of Semantics 15*: 83-113.

Bestgen, Y. & Vonk, W. (1995). The role of temporal segmentation markers in discourse processing. *Discourse Processes 19*: 385-406.

Black, J.B. & Bern, H. (1981). Causal coherence and memory for events in narratives. *Journal of Verbal Learning and Verbal Behavior 20*: 267-275.

Bloom, L. (1991). *Language development from two to three.* Cambridge: Cambridge University Press.

Bloom, L., Lahey, M., Hood, L., Lifter, K. & Fiess, K. (1980). Complex sentences: Acquisition of syntactic connectives and the semantic relations they encode. *Journal of Child Language 7*: 235-261.

Britton, Bruce K. (1994). Understanding expository text: Building mental structures to induce insights. In: Morton Ann Gernsbacher (eds.), *Handbook of psycholinguistics*, 640-674. New York: Academic Press.

Britton, Bruce K., Glynn, S.M., Meyer, B.J.F. & Penland, M.J. (1982). Effects of text structure on use of cognitive capacity during reading. *Journal of Educational Psychology 74*: 51-61.

Cozijn, R. (2000). Integration and inference in understanding causal sentences. Tilburg University: Doctoral Dissertation.

Degand, L., Lefèvre, N. & Bestgen, Y. (1999). The impact of connectives and anaphoric expressions on expository discourse comprehension. *Document Design 1*: 39–51.

Degand, L. & T. Sanders (2002). The impact of relational markers on expository text comprehension in L1 and L2. *Reading and Writing 15 (7-8)*: 739-757.

Ducrot, Oswald (1980). Essai d'application: MAIS - les allusions à l'énonciation – délocutifs, performatifs, discours indirect. In: Herman Parret (ed.), *Le langage en context: Etudes philosophiques et linguistiques de pragmatique*, 487-575. Amsterdam: John Benjamins.

Evers-Vermeul, J. & T. Sanders (2009). The emergence of dutch connectives; how cumulative cognitive complexity explaisn the order of acquisition. *Journal of Child Language 36(4)*: 829-854.

Gaddy, M.L., van den Broek, P. & Sung, Y-C. (2001). The influence of text cues on the allocation of attention during reading. In: T. Sanders, J. Schilperoord &W. Spooren (eds.), *Text representation: Linguistic and psycholinguistic aspects*, 89-110. Amsterdam/Philadelphia: Benjamins.

Gernsbacher, M.A. & Givón, T. (eds.) (1995). *Coherence in spontaneous text*. Amsterdam/ Philadelphia: John Benjamins.

Grosz, B. J. & Sidner, C. L. (1986). Attention, intentions and the structure of discourse. *Computational Linguistcs 12*: 175-204.

Haberlandt, K. (1982). Reader expectations in text comprehension. In: J.F. Le Ny & W. Kintsch (eds.), *Language and comprehension*, 239-249. Amsterdam: North-Holland Publishing.

Haberlandt, K. & Bingham, G. (1978). Verbs contribute to the coherence of brief narratives: reading related and unrelated sentence triples. *Journal of Verbal Learning and Verbal Behavior 17*: 419- 425.

Kamalski, J., Sanders, T. & Lentz, L. (2008). Coherence marking, prior knowledge, and comprehension of informative and persuasive texts: Sorting things out. *Discourse Processes 45*: 323- 345.

Katz, E.W. & Brent, S.D. (1968). Understanding connectives. *Journal of Verbal Learning and Verbal Behavior 7*: 501-509.

Keenan, J.M., Baillet, S., D. & Brown, P. (1984). The effect of causal cohesion on comprehension and memory. *Journal of Verbal Learning and Verbal Behavior 23*: 115-126.

Lang, Ewald. (1984). *The semantics of coordination*. Amsterdam: John Benjamins.

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

Levinson, S.C. (2000). *Presumptive meanings. The theory of generalized conversational implicature.* Cambridge, MA: MIT Press.

Loman, N.L. & Mayer, R.E. (1983). Signaling techniques that increase the understandability of expository prose. *Journal of Educational Psychology 75*: 402-412.

Lorch, R.F. & Lorch, E.P. (1986). On-line processing of summary and importance signals in reading. *Discourse Processes 9*: 489-496.

McNamara, D. S., & Kintsch, W. (1996). Learning from texts: Effects of prior knowledge and text coherence. *Discourse Processes 22*: 247-288.

Meyer, B.J.F. (1975). *The organization of prose and its effect on memory.* Amsterdam: North-Holland Publishing.

Meyer, B.J.F., Brandt, D.M. & Bluth, G.J. (1980). Use of top-level structure in text: Key for reading comprehension of ninth-grade students. *Reading Research Quarterly 16*: 72-103.

Myers, J.L., Shinjo, M. & Duffy, S.A. (1987). Degree of causal relatedness and memory. *Journal of Memory and Language 26*: 453- 465.

Millis, K.K., Graesser, A.C. & Haberlandt, K. (1993). The impact of connectives on the memory for expository texts. *Applied Cognitive Psychology 7*: 317-339.

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

Mulder, G. (2008). Understanding causal coherence relations. Doctoral dissertation, Utrecht University, The Netherlands.

Noordman, L.G.M. & Vonk, W. (1997). The different functions of a conjunction in constructing a representation of the discourse. In: J. Costermans & M. Fayol (eds.), *Processing interclausal relationships. Studies in the production and comprehension of text*, 75-93. Hillsdale, New Jersey: Lawrence Erlbaum.

Noordman, L.G.M. & Vonk, W. (1998). Memory-based processing in understanding causal information. *Discourse Processes 26*: 191-212.

Oakhill, J. & Garnham, A. (eds.) (1992). *Discourse representation and text processing*. Hove, UK: Lawrence Erlbaum. [Also published as a special issue of *Language and Cognitive Processes*.]

Piaget, J. (1961 [1924]). Les mécanismes perceptifs [The perceptual mechanisms]. Paris: Presses Universitaires de France.

Rayner, Keith. (1998). Eye movements in reading and information processing. 20 years of research. *Psychological bulletin 124(3)*: 372-422.

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

Sanders, T.J.M. & Noordman, L.G.M. (2000). The role of coherence relations and their linguistic markers in text processing. *Discourse Processes 29*: 37-60.

Sanders, T. &W. Spooren (2001). Text representation as an interface between language and its users. In: T. Sanders, J. Schilperoord & W. Spooren (eds.), *Text representation: Linguistic and Psycholinguistic aspects*, 1-25. Amsterdam/Philadelphia: John Benjamins.

Sanders, T.J.M. (2005). Coherence, causality and cognitive complexity in discourse. In: M. Aurnague, M. Bras, A. Le Draoulec & L. Vieu (eds.), Proceedings/Acts SEM- 05, First International Symposium on the exploration and modeling of meaning, 105- 114.

Schank, R. C. (1975). The structure of episodes in memory. In: D. G. Bobrow & A. Collins (eds.), *Representation and understanding: Studies in cognitive science*. New York: Academic Press.

Spyridakis, J.H. & Standal, T.C. (1987). Signals in expository prose: Effects on reading comprehension. *Reading Research Quarterly 22*: 285-298.

Townsend, D.J. (1983). Thematic processing in sentences and texts. *Cognition, 13*: 223-261.

Trabasso, T. & Sperrey, L. (1985). Causal relatedness and importance of story events. *Journal of Memory and Language 24*: 595-611.

Trabasso, T., & van den Broek, P. (1985). Causal thinking and the representation of narrative events. *Journal of Memory and Language 24*: 912- 630.

Traxler, M. J., Bybee, M. D. & Pickering, M. J. (1997). Processing causal and diagnostic statements in discourse. *Journal of Experimental Psychology: Learning, Memory, and Cognition 2*: 88-101.

Van den Broek, P. (1990). Causal inferences and the comprehension of narrative text. In: A.C. Graesser & G.H.Bower (eds.), *The psychology of learning and motivation*, 275-196. New York: Academic.

Van Dijk, T.E. & Kintsch, W. (1983). *Strategies of discourse comprehension*. San Diego, California:

Academic Press.

Wolfe, M.B.W., Magliano, J.P., & Larsen, B. (2005). Causal and Semantic Relatedness in Discourse Understanding and Representation. *Discourse Processes 39*: 165- 187.