# An analytic and cognitive parameterization of coherence relations*

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*Abstract*

*An analytic and cognitive parameterization of coherence relations is proposed that contains the categories* TYPE (CAUSAL, TEMPORAL, ADDITIVE), POLARITY (POSITIVE, NEGATIVE), *and* DIRECTION (FORWARD, BI-DIRECTIONAL, *and* BACKWARD). *Evidence for the parameterization comes from the first of a series of studies. An eye-tracking study and a self-paced reading-time experiment provide tentative cognitive evidence for the proposed types of coherence relations.*

*Keywords:* *coherence; interclausal relationships; connectives; discourse processing; comprehension.*

Can an analytic or cognitive system underlying coherence relations be defined, and if so what would that system look like? In recent years the interest in this question and in interclausal relationships in particular has increased. Some studies have looked at this question from a theoretical linguistic perspective (Halliday and Hasan 1976; Martin 1992), some from a computational linguistic perspective (Hobbs 1985; Knott 1996; Mann and Thompson 1987), and some from a psycholinguistic perspective (Sanders et al. 1992). The current study addresses this question from both an analytic and a processing point of view by proposing an economical parameterization of interclausal relationships based on existing proposals and providing some first cognitive evidence from a series of studies.

## 1. Cohesion and coherence

Text comprehension involves the construction of a coherent mental representation of the situations described by the text (Gernsbacher 1990).

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I use the term *coherence* for these representational relationships and *cohesion* for the textual indications that coherent representations should be built (Louwerse and Graesser, in press). It is widely acknowledged that coherence cannot lie exclusively within the text. Instead, it is in the mental representation of the reader or the writer (Garnham and Oakhill 1996; Zwaan and Radvansky 1998). However, potential cohesion relations can be identified in the text. To identify the distinction between cohesion and coherence is important, as it can help us in text and comprehension analysis, for instance by pointing out why an ambiguous cohesion marker can be comprehended as an unambiguous coherence relation. In other words, it is predicted that cohesion is sufficient, although not necessary, for coherence.

Following Givón (1995) and Kintsch (1995), grammar-driven and vocabulary-driven cohesion and coherence are assumed here. Grammar-driven cohesion primarily refers to the grammatical information in the text that cues grammar-based inferences. Vocabulary-driven cohesion primarily refers to the (lexical) vocabulary of the clause that cues knowledge-based inferences. Human language uses these two modes of discourse processing, the vocabulary-driven (pregrammatical) mode and the grammar-driven (grammatical) mode.

Furthermore, a distinction is assumed between local and global relations. Both cohesion and coherence are locally and globally structured. The comprehender finds local cohesion relations between adjacent clauses in the text, as well as global cohesion links between groups of clauses. This distinction is important, because both local and global cohesion cue comprehenders on how to organize the comprehension process.

The final distinction to be assumed here is between the different sources of coherence. The psycholinguistic literature frequently distinguishes five ways in which coherence can be maintained across text spans. REFERENTIAL coherence is due to appropriate relations between the individuals described in the spans (in particular, the relation of identity), while LOCATIONAL, CAUSAL, TEMPORAL, and ADDITIVE coherence are due to appropriate spatial, causal, temporal, and comparative relations between the spans (Gernsbacher 1990; Givón 1995; Zwaan and Radvansky 1998). A vast amount of psycholinguistic literature has found that the presence of cohesion relations facilitates processing for each of these strands (see Gernsbacher 1990; Zwaan and Radvansky 1998; and Costermans and Fayol 1997 for overviews). Although all five coherence strands can be marked by grammar-driven cohesion cues, only three of them (CAUSAL, TEMPORAL, and ADDITIVE) are prototypically marked by conjunctions.

This study will mainly concern local grammar-driven (CAUSAL, TEMPORAL, and ADDITIVE) cohesion and coherence, although its conclusions

also apply to vocabulary- and grammar-driven cohesion and coherence in general.

## 2. Recurrent categories in taxonomies of coherence relations

An overall comparison of taxonomies of cohesion and coherence relations is difficult, because some taxonomies are fundamentally different from others. Some are data driven and are entirely based on cohesion relations (usually conjunctions) in a language. Examples of these taxonomies are presented in Halliday and Hasan (1976), Knott and Dale (1994), and Martin (1992). Other taxonomies are theory driven. They are based on observations of coherence relations. Mann and Thompson's Rhetorical Structure Theory is an example of such a taxonomy, as are those described by Hobbs (1985) and Sanders, Spooren, and Noordman (1992). A comparison of data-driven taxonomies is easiest, because of the concrete linguistic cues that can be compared. However, a comparison of Halliday and Hasan (1976), Martin (1992), and Knott and Dale (1994) immediately shows that their categories are not related in a one-to-one fashion. Those relations representative for one taxonomy's category are not representative for the same category in others. For instance, about 40 percent of Halliday and Hasan's conjunctions are either not used or different in, or absent from the other taxonomies. The same can be said for about 60 percent of Martin's conjunctions and 70 percent of Knott and Dale's conjunctions. Louwerse (2000) examined the recurrent categories in seven proposals (Halliday and Hasan 1976; Hobbs 1985; Knott and Dale 1994; Martin 1992; Mann and Thompson 1987; Sanders et al. 1993) and found that, despite the obvious differences between these proposals, a comparison shows some clear similarities. They are summarized in the following four groups.

i. CAUSAL, TEMPORAL, and ADDITIVE relations: all proposals use a notion of causality, temporality, and additivity.[1] Examples of the three relations are given in (1a–c). All examples are taken from Halliday and Hasan (1976).

(1) a. CAUSAL: … she felt that there was no time to be lost, as she was shrinking rapidly; *so* she got to work at once to eat some of the other bit. (Halliday and Hasan 1976: 256)

b. TEMPORAL: 'But that must happen very often,' Alice remarked thoughtfully. 'It always happens,' said the Gnat. *After* this, Alice was silent for a minute of two, pondering. (1976: 261)

c. ADDITIVE: My client says he does not know this witness. *Further*, he denies ever having seen her or spoken to her. (1976: 246)

ii. NEGATIVE relations: all taxonomies have some kind of CONTRASTIVE or ADVERSATIVE relations, in addition to their POSITIVE counterparts.

(2) a. POSITIVE: … she felt that there was no time to be lost, as she was shrinking rapidly; *so* she got to work at once to eat some of the other bit. (1976: 256)
b. NEGATIVE: All the figures were correct; they'd been checked. *Yet* the total came out wrong. (1976: 250)

iii. SEMANTIC and PRAGMATIC relations: all taxonomies distinguish relations between events in the world from relations between speech acts.

(3) a. SEMANTIC: … she felt that there was no time to be lost, as she was shrinking rapidly; *so* she got to work at once to eat some of the other bit. (1976: 256)
b. PRAGMATIC: 'And what does it live on?' 'Weak tea with cream in it.' A new difficulty came to Alice's head. 'Supposing it couldn't find any?' she suggested. '*Then* it would die of course.' (1976: 258)

iv. DIRECTION: all taxonomies use a distinction between the order of the clauses that are conjoined (e.g., causes preceding or succeeding effects). This distinction will be called FORWARD and BACKWARD here.

(4) a. FORWARD: … she felt that there was no time to be lost, as she was shrinking rapidly; *so* she got to work at once to eat some of the other bit. (1976: 256)
b. BACKWARD: The next morning she was glad and proud that she had not yielded to scare. *For* he was most strangely and obviously better. (1976: 258)

These shared categories allow us to propose a basic taxonomy of cohesion and coherence relations.

## 3. A proposal for a parameterization of cohesion and coherence relations

On the basis of the recurrent categories in the taxonomies, and in particular on the basis of Sanders, Spooren, and Noordman's (1992, 1993)

proposal, a basic, economical parameterization of cohesion and coherence relations is proposed. This means that the aim is not to describe all cohesion relations available in a language, but to settle for a simple parameterization. Furthermore, because the proposed parameterization will be tested in psycholinguistic experiments, the focus lies on clear unambiguous categories, avoiding composite ones.

Three categories are used in the proposed parameterization: TYPE, POLARITY, and DIRECTION. TYPE contains the categories CAUSAL, TEMPORAL, and ADDITIVE. These relations refer to time and causality (CAUSAL), time alone (TEMPORAL), or neither (ADDITIVE). POLARITY contains the categories POSITIVE and NEGATIVE. In POSITIVE relations the situation presented first is continued in the conjoined situation. On the other hand, in NEGATIVE relations the expected related situation is discontinued. The third category in the taxonomy, DIRECTION, consists of the categories BACKWARD, FORWARD, and BI-DIRECTIONAL, depending on the order of the events in their presentation. The proposed parameterization is illustrated in Figure 1.

The factorial combination of TYPE, POLARITY, and DIRECTION offers eighteen kinds of cohesion and coherence relations, realized in common English cohesion relations. However, because no instances exist of BI-DIRECTIONAL CAUSAL and NEGATIVE TEMPORAL relations and because

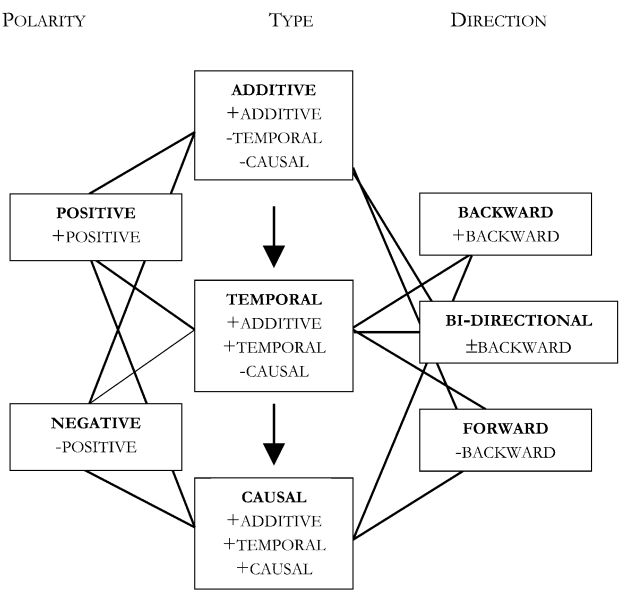


Figure 1. *Overview parameterization*

ADDITIVE relations only occur FORWARD, a total of thirteen relations are actually marked in English. Examples for each of the relations are given in Table 1.

*TYPE*

My proposal is that the parameter values ADDITIVE, TEMPORAL, and CAUSAL specify three points on the same axis. ADDITIVE relations will be defined as [+ADDITIVE], TEMPORAL relations as [+ADDITIVE and +TEMPORAL], and CAUSAL relations as [+ADDITIVE, +TEMPORAL and +CAUSAL]. According to the proposed parameterization, ADDITIVE relations are equivalent to TEMPORAL relations, except for their reference to time, and the latter are equivalent to CAUSAL relations except for their reference to cause.

Furthermore, it is argued that CAUSAL relations imply TEMPORAL relations and TEMPORAL relations imply ADDITIVE relations. This means that temporality is always a prerequisite for (the underlying) causality. The group of ADDITIVE (i.e., non-TEMPORAL) relations contains a number of distinct relations, in particular those signaled by *also*, *similarly*, *furthermore*, and *however*, which signal varieties of similarity or contrast, either in propositional content or argumentative force.

Table 1. *Categories of parameterization*

| TYPE | POLARITY | DIRECTION | Examples |
|---|---|---|---|
| CAUSAL | POSITIVE | BACKWARD | *x* because *y* |
| | | FORWARD | *x* so *y*; because *x*, *y* |
| | | BI-DIRECTIONAL | – |
| | NEGATIVE | BACKWARD | *x* although *y* |
| | | FORWARD | *x* nevertheless *y*; although *x*, *y* |
| | | BI-DIRECTIONAL | – |
| TEMPORAL | POSITIVE | BACKWARD | *x* before *y*, after *x*, *y* |
| | | FORWARD | *x* after *y*; before *x*, *y* |
| | | BI-DIRECTIONAL | *x* while *y*; *y* while *x* |
| | NEGATIVE | BACKWARD | *x* until *y* |
| | | FORWARD | until *x*, *y* |
| | | BI-DIRECTIONAL | – |
| ADDITIVE | POSITIVE | BACKWARD | – |
| | | FORWARD | *x* moreover *y* |
| | | BI-DIRECTIONAL | *x* similarly *y*; *y* similarly *x* |
| | NEGATIVE | BACKWARD | – |
| | | FORWARD | *x* however *y* |
| | | BI-DIRECTIONAL | *x* alternatively *y*; *y* alternatively *x* |

*POLARITY*

The POLARITY parameter can be defined informally using the notion of "opposition": in a NEGATIVE POLARITY relation there is opposition, while in a POSITIVE POLARITY relation there is none. A slightly more formal definition can be given by making reference to an underlying, possibly implicit, basic relation between the related text spans, as in Sanders, Spooren, and Noordman (1992). In a POSITIVE relation between two spans *x* and *y*, the underlying relation holds directly for *x* and *y*, while in a NEGATIVE relation, the underlying relation holds between *x* and the negation of *y*. The TYPE parameter can then be taken to describe the underlying relation, rather than the surface relation, between *x* and *y*; in other words, the underlying relation can either be ADDITIVE, TEMPORAL, or CAUSAL.

A study by Lagerwerf (1998) gives an interesting refinement to the notion of underlying CAUSAL relations. Lagerwerf argues that the relations which underlie *because* and *although* are presupposed, rather than asserted. The presupposed material in both cases is a causal rule, or rule of inference. For instance, both sentences (5a) and (5b) bear the presupposition (5c):

(5) a. Bill kissed Monica, although he didn't like her.
b. Bill kissed Monica, because he liked her.
c. Normally, if somebody kisses a person, he/she likes him/her.

In the *because*-sentence (5b), the expectation (5c) is explicitly conveyed; in the *although*-sentence (5a), it remains implicit. Moreover, in the *although*-sentence the expectation is negated. Lagerwerf justifies the presupposition analysis using a number of standard linguistic tests for presuppositions.

The notion of POLARITY can be extended to ADDITIVE relations: POSITIVE ADDITIVE relations signal similarity (*similarly*) or conjunction (*and*), while NEGATIVE ADDITIVE relations signal contrast (*however*) or disjunction (*or*). The difference between the underlying relations involved in similarity/contrast and conjunction/disjunction still needs to be formalized, as well as their differences with CAUSAL underlying relations, but it is clear that they are both non-TEMPORAL.

The notion of POLARITY can also arguably do service for TEMPORAL relations. Most TEMPORAL relations have POSITIVE POLARITY, but the relation signaled by *until* is an exception: *x until y* tells us that the situation where *y* occurs brings about or signals a situation where *x* stops occurring. Note, however, that the necessary notion of negation here is a little different from that in earlier cases, because it must make reference to the aspectual type of *x* and *y*; again, this is a topic for further work.

*DIRECTION*

In several of the taxonomies discussed earlier, a notion of order among the text segments was defined. To describe the difference between conjunctions like *because* and *although* on the one hand and *so* and *nevertheless* on the other (in the first, the text segment describing the effect precedes the segment describing the cause, in the latter vice versa), the notions of FORWARD and BACKWARD have been used. The question is what we do with relations like *similarly* and *correspondingly*, which Martin (1992) calls "comparative" and Knott and Dale (1994) term "similarity." These cases are labeled BI-DIRECTIONAL in the parameterization.

Although the DIRECTION parameter is important, it clearly differs from the TYPE and POLARITY parameters. Where the TYPE and POLARITY parameters concern the semantics of the cohesion relation, DIRECTION only concerns its presentation.

*Exclusion of SEMANTIC versus PRAGMATIC*

Although all taxonomies of cohesion and coherence relations incorporate a distinction between SEMANTIC and PRAGMATIC relations, this distinction has been left out of the current proposal. First of all, the distinction is the weakest, both text analytically and empirically. It is, for instance, not entirely clear how many levels of representation can be distinguished. Some (Sanders et al. 1992, 1993) argue for a bipartite distinction between the propositional content of two related utterances and between the speech acts. Others (Sweetser 1990) argue for a tripartite distinction, which in addition to the bipartite distinction divides the relation between speech acts into two: an EPISTEMIC relation that holds between events in the world and observations and conclusions, and a SPEECH-ACT relation that holds between the speech act and the justification and conclusion of performing the speech act. Based on problems with both the bipartite and tripartite distinctions, Knott (in press) suggests an intention-based bipartite distinction by redefining PRAGMATIC relations in terms of the intended effect of the utterances. Text linguists have not yet solved this issue empirically either. Sanders, Spooren, and Noordman (1992), for instance, tested their taxonomy and asked discourse analysts to find an appropriate label for coherence relations presented in a set of sentence pairs. Subjects showed most confusion for the difference between SEMANTIC and PRAGMATIC relations. Sanders' (1997) explanation for the confusion among subjects is the lack of context in which these relations occur. In his experiment, subjects read both argumentative and descriptive texts with a SEMANTIC relation, a PRAGMATIC relation, or a "chameleon" (both SEMANTIC and PRAGMATIC) one. Subjects were asked to paraphrase the

relations by choosing from a list of vocabulary-driven cohesion relations (e.g., *My argument for this is, the cause of this is*) and were indeed able to distinguish between SEMANTIC and PRAGMATIC relations, suggesting that the relations are dependent on context.

Since the distinction seems to be the weakest according to existing text-analytic and empirical studies, it is not included in the current cognitively inspired and economical taxonomy.

## 4. Cognitive evidence for the parameterization of coherence relations

Various studies have looked at how we comprehend clauses that include grammar-driven cohesion relations, either to get a better understanding of language comprehension, or to provide evidence for a taxonomy of coherence relations, or both.

Sanders, Spooren, and Noordman's (1992) theory is a psychologically plausible one, whose principles apply to all coherence relations, ordering them along the lines of four cognitive basic primitives:

1. a BASIC OPERATION, that distinguishes between CAUSAL and ADDITIVE relations;
2. SOURCE OF COHERENCE that distinguishes between SEMANTIC relations and PRAGMATIC relations;
3. ORDER OF SEGMENTS, distinguishing between cause-precedes-effect and effect-precedes-cause relations; and
4. POLARITY, distinguishing between correspondence between the two texts segments and the negative counterpart of the two text segments.

The BASIC OPERATION is thus similar to the category of TYPE (except for the TEMPORAL relations), POLARITY to that of POLARITY, and ORDER OF SEGMENTS to the DIRECTION category (except for the BI-DIRECTIONAL relations). Sanders, Spooren, and Noordman tested the success of classification and the psychological plausibility of their taxonomy. In a series of classification experiments they found that both discourse analysts and undergraduate students agreed most on the POLARITY category and least on the SOURCE OF COHERENCE relation. In a card-sorting task (Sanders et al. 1993), cluster analyses showed that results of groupings of POLARITY and BASIC OPERATION were strong, while no evidence was found for the ORDER and only little evidence was found for SOURCE OF COHERENCE. These experiments suggest there is evidence for TYPE and POLARITY relations at least.

But it does not necessarily follow from the comprehenders' ability to distinguish between categories that these categories also play a cognitive role in comprehension. The conclusion might be that some categories

are more obvious than others. To provide processing evidence for the proposed parameterization we need to turn to subtle on-line comprehension studies. Several studies have investigated how textual cohesion supports representational coherence for both POSITIVE and NEGATIVE relations. For instance, CAUSAL relations are processed faster than TEMPORAL ones, which are processed faster than ADDITIVE relations (Caron et al. 1988; Deaton and Gernsbacher, in press; Sanders and Noordman 2000). In general, CAUSAL relations are believed to play a facilitating role in text comprehension (see Noordman and Vonk 1997; Cozijn 2000). POSITIVE relations are generally processed faster than NEGATIVE ones (Townsend 1983). The problem with many of these studies is that the materials are biased towards a particular type of coherence relation. To answer the question with regard to the effects of cohesion categories on the comprehension process, we need texts that are controlled for any information that can be obtained from the syntax and semantics of the related clauses. There are two ways to do this: one is to use natural discourse, which has the disadvantage that controlling for variables is difficult. The other is to use identical materials in which different cohesion relations can be used. Both options are investigated here in an eye-tracking study and a reading-time experiment. To limit the number of variables in these experiments, the category DIRECTION will be excluded from the experiments.

Based on the results of aforementioned studies, three related hypotheses are defined. The parameterization hypothesis predicts general differences in processing time. The TYPE and POLARITY hypotheses specify these differences.

i. *Parameterization hypothesis*
Clauses conjoined by different combinations of the parameters require different processing times for the different TYPE parameters and the different POLARITY parameters.

i(a). *TYPE hypothesis*
CAUSAL cohesion and coherence relations are processed faster than TEMPORAL relations, which are processed faster than ADDITIVE relations.

i(b). *POLARITY hypothesis*
POSITIVE cohesion and coherence relations are processed faster than NEGATIVE relations.

### 4.1. *Experiment 1*

An explorative eye-tracking study investigated behavioral evidence for the parameterization and its effects on processing. The effects were measured

by examining the fixations for interclausal conjunctions. The experiment investigated the reading process in its most natural form, that is, with subjects reading a piece of naturally occurring text.[2]

## *Method*

*Subjects.* Ten subjects taken from the Glasgow University eye-tracker list participated in the experiment. All subjects were native speakers of English and had normal (uncorrected) vision. Some subjects had participated in other eye-tracking experiments.

*Materials.* Subjects read an extract of the novel *An Awfully Big Adventure* by Beryl Bainbridge, drawn from the British National Corpus. They read ten to thirty screens of text, depending on their reading speed. The text contained uppercase and lowercase letters and the paragraph layout was removed. Each screen did not exceed 10 lines in length or 65 characters in width. The end of a screen and beginning of a new screen were separated by sentence and—where possible—paragraph boundaries.

A total of 89 interclausal conjunctions occurred in the material. They are classified in one of the six cohesion and coherence relations: POSITIVE CAUSAL, NEGATIVE CAUSAL, POSITIVE TEMPORAL, NEGATIVE TEMPORAL, POSITIVE ADDITIVE, NEGATIVE ADDITIVE (see Table 2). Only conjunctions considered as prototypical for a category were used. An independent judge checked the categorization of conjunctions, following the definitions of the categories of the parameterization, and agreed on the classification.

Table 2. *Conjunctions in Bainbridge (1989)*

| Conjunction | TYPE | POLARITY |
|---|---|---|
| although | CAUSAL | NEGATIVE |
| and | ADDITIVE | POSITIVE |
| because | CAUSAL | POSITIVE |
| before | TEMPORAL | POSITIVE |
| besides | ADDITIVE | POSITIVE |
| but | ADDITIVE | NEGATIVE |
| for | CAUSAL | POSITIVE |
| however | ADDITIVE | NEGATIVE |
| if | CAUSAL | POSITIVE |
| though | CAUSAL | NEGATIVE |
| until | TEMPORAL | NEGATIVE |
| when | TEMPORAL | POSITIVE |
| whenever | TEMPORAL | POSITIVE |

*Procedure*. The eye movements of each subject were recorded using a SRI Dual Purkinje 5.5. eye-tracker. The tracker had an angular resolution of 10′. The tracker monitored only the gaze location of the subjects' right eye. The text was presented on a computer screen 70 centimeters from the subjects' eyes.

The accuracy of the eye-tracker was verified before the subject started reading the passage. Each fixation was represented by an $x$ and $y$ screen co-ordinate, a starting time, and an ending time. This eye-tracker output was converted to provide data on gazes at each word. Fixations of less than 80 milliseconds duration in situations where two fixations were within one character space were assimilated to the next fixation. Other very short fixations (of less than 40 milliseconds and within three character spaces of the nearest word) were deleted. Fixations on interword spaces were attributed to the right, due to the right-centered perceptual span.

Subjects were seated in front of a computer screen and were asked to read naturally and to make sure they understood the text. First, a calibration procedure was carried out. The accuracy of the eye-tracker was verified before the subject read each passage and, if necessary, the eye-tracker was realigned.

To initiate the reading of the passage, the reader had to look at a fixation point. This point was located at the position where the first word of the new screen would appear. When the subject pressed a button a screen of text was presented on the monitor until the subject pressed a response button indicating he/she had finished reading the screen.

*Results*

Mean reading times were computed after outliers were removed. Outliers were those reading times exceeding 2.5 standard deviations (SD) from the mean. A total of 1.9 percent of all fixated words were accordingly removed from the analysis. The average fixation time on all words was 247 milliseconds (SD 75.03), with a range from 16 to 551 milliseconds. With 35 percent of the words not fixated and 24 percent of the words receiving two or more regressions, subjects averaged 270 words per minute on the text. Subjects regressed a maximum of five times to one word. Regressions were made to 21.19 percent of the first-pass fixations, of these second fixations 17.09 percent were themselves regressed. These results correspond to the results generally found in other eye-tracking experiments (see Rayner and Pollatsek 1989).

As not all subjects read all screens, a total of 765 encounters with the conjunctions classified in terms of the parameterization were used for the analysis. Outliers among the conjunctions were removed from the analysis (2.6 percent of the data), using the same method as for general

fixations. The average fixation time on conjunctions was 253 milliseconds (SD 94), with a range from 57 to 789 milliseconds.

*Regressions to previously fixated words.* The frequency of regressions to previously fixated conjunctions shows potential difficulties with processing cohesion relations. CAUSAL and TEMPORAL relations received more regressions than ADDITIVE relations ($\chi^2_F = 13.474$, df = 2, $p = .001$). Furthermore, NEGATIVE relations received more regressions than did POSITIVE relations (T = 0, z = −2.805, $p = .005$, N = 10). According to the TYPE and POLARITY hypotheses, ADDITIVE relations receive more regressions than TEMPORAL relations, and TEMPORAL more than CAUSAL relations, while POSITIVE relations require fewer regressions than NEGATIVE ones. Results for POLARITY relations this show the predicted patterns, but results for TYPE relations do not. Although evidence for the parameterization hypothesis is provided, the TYPE hypothesis is falsified.

*Fixation times.* To analyze the first-pass fixation times of the conjunctions, a residual correction was carried out on the unadjusted reading times using the method proposed in Ferreira and Clifton (1986) and Trueswell, Tanenhaus, and Garnsey (1994), in order to account for differences in word length, word frequency and the position of the conjunction. The best linear fit between the selected independent variables and the first-pass fixation time was calculated for each subject. All linear variance related to these variables was removed by subtracting the predicted fixation time from the actual fixation time. A multiple regression analysis was carried out on the first-pass fixation times of the cohesion relations, with word frequency, word length, position on line (beginning or end) and position on screen (beginning or end) as independent variables. Significant effects ($p < .01$) were attributed to word frequency, last position on the line and first position on the screen ($R_2 = .119$, $F(5, 345) = 9.327$, $p < .01$).[3] Residuals of the mean of the first-pass fixation times (linear variance that cannot be explained by these independent variables) were saved as the dependent variable for further analysis. An analysis of variance was carried out on the reading times with items (conjunctions) as random factors. Because of the heterogeneity of the material, no analysis could be carried out with items as a random factor.

According to the parameterization hypothesis, effects were expected for both TYPE and POLARITY. Effects of the first-pass fixations on conjunctions were only found for TYPE ($F(2, 18) = 3.938$, $MS_e = 610.371$, $p = .038$). However, contrary to the TYPE hypothesis, CAUSAL relations were processed most slowly and ADDITIVE relations most quickly

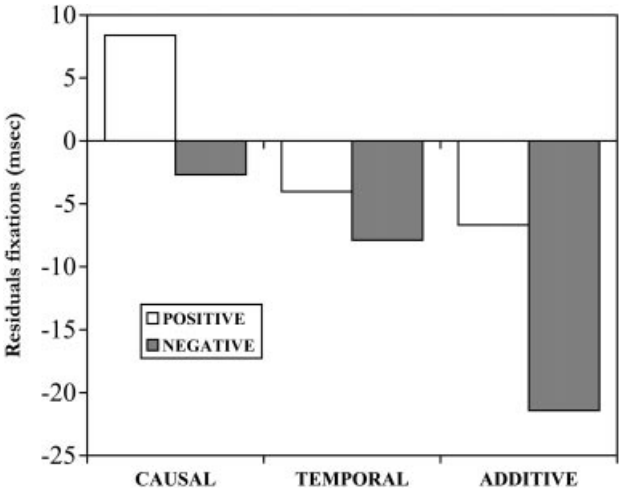


Figure 2. *Mean residuals of first-pass fixation times*

(see Figure 2). A planned comparison showed that this effect came from ADDITIVE relations versus CAUSAL and TEMPORAL relations ($F(1, 9) = 6.665$, $MS_e = 442.930$, $p = .013$).

*Discussion*

In this study some evidence was found for the parameterization hypothesis, with effects for both TYPE and POLARITY parameters. More specifically, as predicted by the POLARITY hypothesis, POSITIVE relations have a facilitating effect on processing coherence relations. They tend to receive less regressions than NEGATIVE relations. However, no significant POLARITY effect was found for fixation times. Although TYPE effects were found, the TYPE hypothesis was falsified: CAUSAL and TEMPORAL relations had higher reading times than ADDITIVE relations did. Furthermore, CAUSAL relations also appear to be regressed more often than TEMPORAL or ADDITIVE relations. Both the fixation times and number of regressions show that CAUSAL and TEMPORAL relations require more regressions and higher fixation times than do ADDITIVE relations.

What could be the reason that results that are the opposite of what is predicted based on results in existing studies are found? The answer might lie in the area of interest. We have only looked at the eye fixations on the conjunctions, while it might well be possible that different results are found at other positions in the clause. Let us assume that when comprehenders read a conjunction like *although*, they need to understand that the event in the subordinated clause occurred contrary

to expectations. With the conjunction *because*, a CAUSAL relation can thus already be anticipated, whilst more information from the text is needed for *although*. A similar argument can be made for the TYPE category. In the case of ADDITIVE cohesion relations, the comprehenders can create ADDITIVE, TEMPORAL, and CAUSAL coherence relations. In temporal relations both TEMPORAL and CAUSAL relations can be created. More textual information is needed to decide which relation is to be established. In CAUSAL relations comprehenders are already cued on which relation to build. If this explanation is correct, we should not just look at total processing times for cohesion relations, but also at their position in the clause. This would mean, in the case of POSITIVE and CAUSAL (and to a lesser extent TEMPORAL) relations, that comprehenders will slow down at the conjunction to anticipate the relation, and, if no careful analysis of the text is needed, speed up to the end of the clause where the integrated information is wrapped up (see also Millis and Just 1994). We would then expect different effects for those conjunctions that require textual information to be established and those that do not. Because of the materials in this experiment, such a prediction cannot be tested here.

The current results should, however, be treated with caution. First, results only concern fixations on conjunctions. This is not only a limited area of interest, but fixations might also be influenced by vocabulary-driven cohesion. Secondly, the analysis of variance was only carried out with subjects as a random factor. Particularly in language experiments we know that an analysis with items as random factors is desirable. A noncumulative self-paced reading-time task, in which subjects are forced to read every single word, would circumvent this problem.

### 4.2. *Experiment 2*

To solve the problems with the previous experiment, a reading-time experiment was conducted using unbiased text with representative markers for each of the six coherence relations. Because the same texts were used throughout, unwanted contextual effects of frequency, word length, syntax, and morphology are reduced to a minimum.

#### 4.2.1. *Data-collection experiment*

A data-collection experiment was prepared first, to ensure all texts were natural. Based on the results of the data-collection experiment, texts that are considered most natural in all conditions can be selected for the reading-time experiment. Furthermore, naturalness scores might give us information related to the three hypotheses.

*Method*

*Subjects*. Forty-eight undergraduate students from the Faculty of Arts at the University of Edinburgh participated in this experiment on a voluntary basis or to fulfill their course requirement. All subjects were native speakers of English.

*Materials*. The materials consisted of 86 three-line texts. The second and third clause of each text was conjoined by either a POSITIVE CAUSAL, NEGATIVE CAUSAL, POSITIVE TEMPORAL, NEGATIVE TEMPORAL, POSITIVE ADDITIVE, or NEGATIVE ADDITIVE relation. The choice of the relations was determined by the commonness of the word in daily use and nonambiguity of the word, i.e., the relation should minimally interfere with other coherence relations. Taking into account these two conditions, the relations shown in Table 3 were selected as representative for each of the categories.

The materials were constructed in such a way that very long and uncommon words were avoided. Although a Latin-Square design was used to control for these confounds, it was argued that they would make general processing more difficult, eventually resulting in unwanted carry-over effects into other texts. Furthermore, many different scenarios were used, so that the subject could not anticipate a relation based on the previous scenario.

The following text is an example of the texts used in this experiment, where [CR] is a placeholder for each of the six cohesion relations.

(6) a. My neighbor played saxophone
b. I didn't like it
c. *[CR]* he practiced every day

The interpretation of text (6) with each of the relations is as follows:

i. POSITIVE CAUSAL: *because*
My neighbor played saxophone every day. His daily practice annoyed me.

ii. NEGATIVE CAUSAL: *although*
Despite his daily practice, my neighbor's saxophone playing annoyed me.

Table 3. *Cohesion relations used in data collection*

| | CAUSAL | TEMPORAL | ADDITIVE |
|---|---|---|---|
| POSITIVE | *because* | *Later* | *What's more* |
| NEGATIVE | *although* | *until* | *However* |

iii. POSITIVE TEMPORAL: *Later*
I did not like the saxophone playing of my neighbor at time *t*. At time $>t$ he practiced every day.

iv. NEGATIVE TEMPORAL: *until*
I did not like the saxophone playing of my neighbor at time *t*. But at time $>t$ he practiced every day and from that moment on I appreciated it.

v. POSITIVE ADDITIVE: *What's more*
I did not like the saxophone playing of my neighbor. To make things worse, he also practiced every day.

vi. NEGATIVE ADDITIVE: *However*
I did not like the saxophone playing of my neighbor, but at least he practiced every day.

Each clause in the text contained an average of seven words, with an average of five characters per word. Eight fillers were used. They were constructed so that they would not be considered natural in any of the conditions. As all texts were constructed with the intention of providing natural interpretations in all conditions, these fillers were needed to ensure occurrences of sentences that would definitely be interpreted as unnatural. Two independent judges helped to adjust grammaticality and plausibility. A Latin-Square design was used to allow each item to be judged in each cohesion and coherence relation by a different group, while each group encountered all conjunctions with equal frequency. The order of the texts was carefully randomized.

*Procedure*. Subjects were asked to show how naturally the third line of a three-line paragraph went with the previous two lines by circling one option on a seven-point scale and to follow their initial reactions as there were no wrong answers. Although there was no time constraint, they were encouraged to proceed without backtracking. Two examples were given, followed by two practice texts.

*Results*

The main aim of the data-collection experiment was to select texts for the reading-time experiment that were considered natural in all six conditions. A prerequisite for the selection was an agreement among subjects. Intraclass correlation coefficients showed an overall significant agreement on the naturalness among subjects (Cronbach's Alpha = .82). An analysis of variance with the average subject rating as dependent variable showed a significant effect for the naturalness scores between TYPE—but not between POLARITY—relations ($F(2, 100) = 22.22$, $p < .001$). The actual

scores show that clauses conjoined by CAUSAL relations are generally considered more natural than those with TEMPORAL or ADDITIVE relations (see Table 4). The differences between agreement scores suggest further evidence for the TYPE relations in the parameterization hypothesis.

4.2.2. *Reading-time experiment*
With the results from the data-collection experiment, a noncumulative self-paced reading-time experiment was conducted to test the three hypotheses.

*Method*

*Subjects*. Forty-eight students from the University of Edinburgh participated in this experiment. Half of them participated for course credit. The other half were paid for their participation. The three groups were divided equally over the conditions in the experiment. All subjects were native speakers of English and had normal or corrected-to-normal vision. None of them had participated in the data-collection study.

*Materials*. Thirty-six texts were selected on the basis of the results of the data-collection experiment. Subjects considered these texts as most natural in all six conditions. In addition, 16 filler texts were used. All texts were followed by a question that related to the first, second, or third clause of the sentence. Only the filler items contained questions related to the third clauses, as the meaning of these clauses varied. Questions were used to check whether subjects indeed comprehended the text, as well as to stimulate them to read as naturally as possible.

*Procedure*. The experiment was carried out on Apple Macintosh computers running the PsyScope package (Cohen et al. 1993). Reading times were measured by a standard Carnegie Mellon button box.

Table 4. *Mean ratings naturalness*[a]

| POLARITY | TYPE | | | |
|---|---|---|---|---|
| | CAUSAL | TEMPORAL | ADDITIVE | |
| POSITIVE | 4.44 (.09) | 3.89 (.11) | 3.51 (.10) | 3.95 (.07) |
| NEGATIVE | 4.00 (.09) | 4.21 (.10) | 3.80 (.11) | 4.00 (.07) |
| | 4.22 (.08) | 4.05 (.08) | 3.66 (.09) | |

[a]Error rates in parentheses.

Subjects were seated in front of a computer screen in separate booths. First, subjects were asked to fill out some personal details: town and country of residence, town and country where they had spent most of their childhood, language of community between the ages of one and ten. These questions were to ensure that the subject was a native speaker of English. Next, the instructions for the experiment were presented. When subjects hit a button, the first word of the first sentence appeared. Subsequently, each time they hit this button, the next word of the sentence appeared. In this way, they made their way through each text. Although this way of reading is somewhat strange, they were asked to try to read as naturally as possible, much as they would read a magazine or a newspaper. When they finished reading the last word of the third line and pressed the button again, a question about the text that they had just read appeared.

To answer the question they had to press a 'yes' or 'no' button. The accuracy of the responses was recorded, but the time taken to respond was not. The experiment began with three practice texts followed by 54 experimental texts. After the practice texts and after 18 experimental texts there was a short break.

*Results*

Before the results were analyzed, the data were filtered. Only those texts for which subjects gave the correct answer to the question were selected, as wrong answers may indicate the subject had not understood the text. The wrong answers were equally distributed over all conditions, all texts, and all subjects. Outliers, defined as those values above or below 2.5 standard deviations from the mean, were removed from the analysis. For all dependent variables (reading time for the third clause, number of words after the cohesion relation), less than three percent of the data were accordingly removed. The missing values occurring because of the elimination of wrong answers or outliers were replaced by the mean values for each category of the filtered data.

Two analyses of variance were carried out on the reading times for clauses and words within the third clause, with subjects ($F_1$) and texts ($F_2$) as random factors respectively. As expected, no effects were found for the reading times of the first and second clause (all Fs $>.1$). Contrary to what the parameterization hypothesis would predict, no effects were found for the total reading time of the third clause. For the word-by-word analyses, a series of ANOVAs were carried out on the reading times for the words of the third clause. First, to allow for a comparison between relations, a multiple regression was again carried out on the residuals of reading times on the conjunction, by using the independent variables of word length and frequency ($R_2 = .027$, $F(2, 2301) = 7.245$, $p = .001$). Contrary to

what was expected, no effects were found for the reading time on the conjunction. Analyses were then run for the first, second, and final word of the third (post-cohesion relation) clause, as only these could be found in all texts. The reading times for the first word showed a marginally significant effect for TYPE ($F_1(2, 94) = 6.60$, $MS_e = 754.89$, $p = .002$; $F_2(2, 70) = 2.96$, $MS_e = 1260.85$, $p = .058$), with higher reading times for ADDITIVE relations than for CAUSAL and TEMPORAL ones (see Figure 3). This provides evidence for the TYPE hypothesis, but not for the POLARITY hypothesis.

The reading times for the second word did provide some evidence for both hypotheses, with a pattern similar to those for the first word. A marginal significant effect was found for TYPE ($F_1(2, 94)$, $MS_e = 1389.671$, $p = .034$; $F_2(2, 70) = 2.75$, $MS_e = 1329.95$, $p = .071$), with CAUSAL relations processed faster than ADDITIVE relations, and TEMPORAL relations in between. A significant effect was also found for POLARITY ($F_1(1, 47) = 4.64$, $MS_e = 1977.73$, $p = .036$; $F_2(1, 35) = 6.21$, $MS_e = 1107.06$, $p = .018$), with POSITIVE relations processed faster than NEGATIVE relations. An interaction effect was only significant in the by-subjects ($F_1(2, 94) = 3.79$, $MS_e = 1260.753$, $p = .026$; $F_2(2, 70) = 2.55$, $MS_e = 1406.76$, $p = .086$). The first part of the clause thus shows a pattern similar to what was predicted. The question now is what happens to the end of the clause. The final word of the third clause showed an effect for TYPE ($F_1(2, 94) = 6.17$, $MS_e = 2847.01$, $p = .003$; $F_2(2, 70) = 3.79$, $MS_e = 3480.13$, $p = .027$), for POLARITY ($F_1(1, 47) = 12.93$, $MS_e = 2452.44$, $p = .001$; $F_2(1, 35) = 7.47$, $MS_e = 3184.11$, $p = .01$), and for the interaction between TYPE and POLARITY ($F_1(2, 94) = 3.10$, $MS_e = 2935.82$, $p = .05$; $F_2(2, 70) = 3.13$,

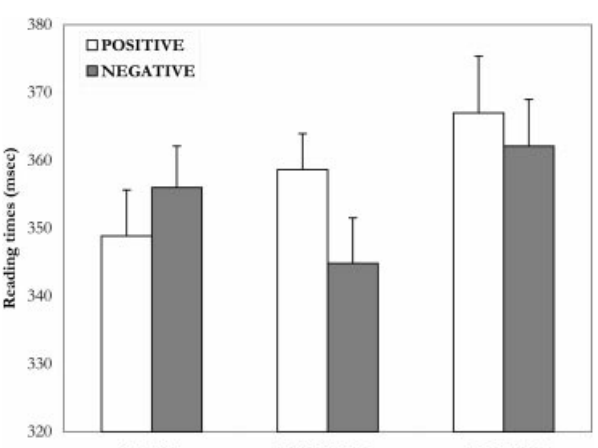


Figure 3. *Reading times for the first word after relation*

$MS_e = 2183.82$, $p = .05$). This time, however, an opposite pattern was found, with higher reading times for CAUSAL relations than for additive relations and higher reading times for POSITIVE relations than for NEGATIVE ones (see Figure 4).

*Discussion*

The reading-time experiment provided some evidence for the parameterization hypothesis, suggesting there are processing differences between the six parameters. However, it only provided partial evidence for the patterns predicted by the TYPE and POLARITY hypotheses. The word-by-word analysis showed that CAUSAL relations were processed faster than ADDITIVE relations were, but also that NEGATIVE relations were processed faster than POSITIVE relations. For the TYPE relations, an opposite pattern was found for the end of the third clause, with ADDITIVE relations being processed faster than CAUSAL relations. POLARITY showed the same pattern for the beginning and the end of the third clause. These results cannot be explained by the naturalness of the clauses, since there is no correlation with the naturalness rating of the data-collection experiment. In sum, the reading-time experiment provides some tentative evidence for the parameterization hypothesis, the TYPE hypothesis and the POLARITY hypothesis, taken into account that different coherence relations are processed at different positions in the clause.

The on-line effects are similar to the explanation provided for the eye-tracking results and are related to those found by Cozijn (2000). In several eye-movement and reading-time experiments, he found processing advantage for the words following the conjunction *because*,

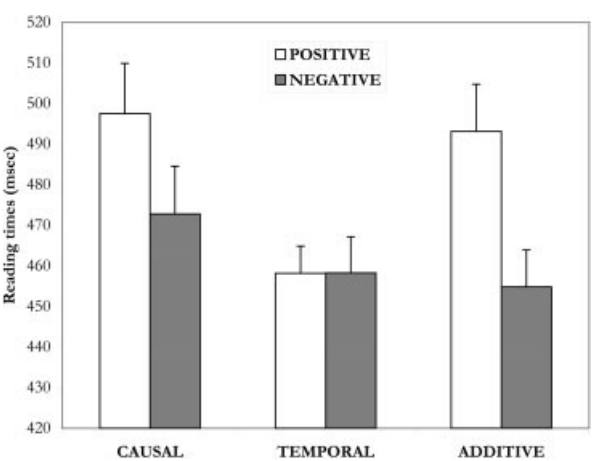


Figure 4. *Reading times for the final word of the third clause*

but a slowing-down effect on the processing toward the end of the clause. The results reported in our reading-time experiment show a similar processing effect; however, the effect depends on the cohesion relation. For *because* sentences, the same pattern was found as in Cozijn (2000): in the beginning of the clause the conjunction is processed faster than other relations, toward the end of the clause there is a slowing-down effect compared to the other relations. However, for ADDITIVE relations an opposite effect is found. How could this effect be explained? As we already suggested, the answer lies in the taxonomy. Information is least specific in the case of ADDITIVE information. According to the proposed parameterization, an implication relation exists between the three TYPE relations. This means that when comprehenders start reading a clause conjoined by an ADDITIVE relation (and to a lesser extent a TEMPORAL relation), they need more information from the text to decide which coherence relation to establish. Once that relation can be built—toward the end of the conjoined clause—processing is easier, hence the decreased processing times. For CAUSAL relations, however, comprehenders are cued as to which coherence relation to establish. Integrating the clause by making inferences and checking the relation against the comprehenders' knowledge requires additional processing times toward the end. This explanation is supported by the current data, but stronger effects and further research are needed to validate this.

## 5. Conclusion

In comprehending discourse, interclausal relationships specified in the text cue comprehenders on how to build a mental representation of the information in the text. Several studies have shown that cohesion facilitates coherence. Many theories of cohesion and coherence relations have been proposed, some of them focusing on the linguistic cues, others emphasizing coherence relations that are grounded in discourse rhetoric and world knowledge. For a cognitive theory of coherence relations, it is desirable that it accounts for a structure among the relations described by that theory. Furthermore, such a theory should concentrate on basic cognitive categories. In this study, a parameterization of local grammar-driven cohesion and coherence relations has been proposed that contains the categories TYPE (CAUSAL, TEMPORAL, ADDITIVE), POLARITY (POSITIVE, NEGATIVE), and DIRECTION (FORWARD, BI-DIRECTIONAL, and BACKWARD).

Tentative evidence for the parameterization comes from an eye-tracking study and a self-paced reading-time experiment. In the eye-tracking study, CAUSAL relations received more regressions than ADDITIVE relations, and NEGATIVE relations received more regressions than POSITIVE relations did.

In the reading-time experiment, similar patterns were found; not on the conjunction itself, however, but on the two words following the conjunction. On the conjunction, processing slows down to anticipate relations. Next, processing speeds up until the end of the clause, where a wrapping-up effect takes place. Indeed, toward the end of the conjoined clause the patterns were reversed. It seems that those relations that require additional processing time toward the beginning of the clause have a processing advantage toward the end of the clause and vice versa. The type of coherence relation and its position in the clause are two important factors in processing. Further research is needed to determine the exact role of these relations in the various positions of the clause. The proposed parameterization could play a helpful role in such research.

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## Notes

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1. TEMPORAL relations are absent in Sanders et al. (1992, 1993). However, the fact that Sanders et al. do not deny a TEMPORAL category (1992:28) and the striking similarities between the three remaining taxonomies of this category make the prominence of TEMPORAL relations clear.
2. I am very grateful to Padraic Monaghan, Richard Shillock and Louise Kelly for allowing me to use these eye movement data.
3. Note that no generalizations can be made about the other variables (e.g. first position on line). First position on line generally does have an effect, but not for the current text with the current conjunctions at various positions.

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