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The facilitating effect of connectives across relations and languages

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The facilitating effect of connectives on discourse processing has been found to be smaller in result relations, compared to other relations (e.g., concession). In addition, connectives are hypothesized to facilitate more in some languages than in others due to typological differences between languages. Speakers of analytic languages (such as English) are assumed to rely more on contextual cues and therefore be less affected by the presence of a connective than speakers of synthetic languages (such as German), who are presumed to rely more on lexical information. We present two self-paced reading studies examining how the effect of a connective depends on the relation type and the language. We find that the presence of a connective facilitates reading more in concession relations than in result relations. This interaction between relation type and relation marking was only found in German.

1 Introduction

The process of reading involves making a coherent mental representation of the text. To do so, the reader needs to know how the different segments of a text are related to each other. For example, the event described in one clause might be the consequence, the cause, or a contrast of what was described in the previous clause. Establishing these connections, also referred to as discourse relations, is necessary to be able to fully comprehend the text. To illustrate, successful comprehension of the Example in 1 requires understanding that the fact that Paul had to run for the bus is caused by the fact that he was late. In other words, the reader has to infer a `result` relation. In Example 2, the second sentence is not causally related to the first sentence, but rather, the second sentence stands in contrast to the information of the first sentence.

(1) Paul was late. He had to run for the bus.

(2) Paul is usually late. Lea is always early.

The relations between sentences can be marked explicitly using linguistic means such as connectives, as illustrated below. These signals serve as "processing instructions," informing the reader which relation needs to be established (van Silfhout et al., 2015). Previous work has shown that relation marking facilitates text comprehension and processing, but only in some sentence positions or for certain relations (cf. Sanders and Noordman, 2000; Cozijn et al., 2011; Kleijn et al., 2019).

(3)   Paul was late **and so** he had to run for the bus.

(4)   Paul is usually late, **but** Lea is always early.

In the present paper, we address two factors that influence the effect of the presence of a connective on discourse processing, following Blumenthal-Dramé (2021).[1] First, the facilitating effect of a connective has been found for different relation types, such as consequence-cause, problem-solution and contrast relations (Cozijn et al., 2011; Sanders and Noordman, 2000; van Silfhout et al., 2015). However, it has been argued that the degree to which the presence of a connective facilitates processing depends on the type of relation (Sanders, 2005; Blumenthal-Dramé, 2021). For example, Köhne-Fuetterer et al. (2021) found that *however* required a stronger update of the discourse representation than *because*, and Kleijn et al. (2019) found that adding causal or contrastive connectives (e.g., *because*, *but*) improved comprehension, while including additive connectives (e.g., *also*) actually impeded it. We examine the facilitative effect of connectives further in the current study, comparing connectives for causal result relations with connectives for two types of negative polarity relations (contrast and concession).

Second, connectives have been shown to facilitate discourse processing of certain relations in various languages, such as Dutch (Kleijn et al., 2019), French (Blochowiak et al., 2022), English (Millis and Just, 1994), and Chinese (Xu et al., 2018). However, languages differ in many respects, which in turn can influence the readers' dependence on connectives (cf. Blumenthal-Dramé, 2021; Yi and Koenig, 2021). For instance, typological properties such as the degree of morphological synthesis, the availability of explicit grammatical markers, or preferred strategies for achieving coherence may shape how strongly readers rely on overt connectives to signal discourse relations. In the current study, we focus in particular on typological variation along the analytic–synthetic continuum, which may affect the extent to which coherence is signaled through linguistic versus contextual cues (Blumenthal-Dramé, 2021). Speakers of analytic languages, which rely less on inflectional morphology, may depend more on pragmatic inference for establishing coherence, whereas speakers of more synthetic languages may be more attuned to explicit linguistic marking. Investigating such differences can provide insight into whether connective processing effects are universal or modulated by language-specific properties.

In the following sections, we discuss previous work that has specifically examined the effect of connectives on text comprehension and processing. In particular, we look at work that has analyzed relation-dependent differences and cross-linguistic differences in connective processing. We then present two self-paced reading studies showing that the effect of relation marking on on-line processing depends on the discourse relation it marks. Contrary to our hypothesis, we do not find evidence that the overall effect of connectives is larger in German. However, the effect of connectives on reading times was found to depend on relation type in German, but not in English.

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1 This study has recently been retracted (The Editors of Discourse Processes, 2024) after we notified the author about an error in her data analysis. The studies reported here were conceptualized as replications and were carried out before these issues were discovered.

2 The effect of connectives on discourse processing

Connectives and cue phrases (such as "this is why") influence discourse processing in various ways. Previous research has shown that they facilitate text comprehension for certain relations (Kleijn et al., 2019; van Silfhout et al., 2015) and elicit expectations about upcoming discourse relations in off-line tasks (Kehler et al., 2008; Scholman et al., 2017; Asr and Demberg, 2020). Furthermore, EEG studies in both English and German have demonstrated that connectives influence readers' expectations about upcoming material during sentence processing (Köhne-Fuetterer et al., 2021; Xiang and Kuperberg, 2015). In particular, the N400 component (a negative-going ERP waveform occurring approximately 400 ms after stimulus onset) is reduced in amplitude for words that are predictable based on the preceding connective. This attenuation aligns with prior findings that the N400 is sensitive to contextual predictability, with more expected words eliciting smaller N400 responses (Kutas and Hillyard, 1984; Van Berkum et al., 2005).

Previous work has shown that connectives lead to shorter reading times of the material directly following the connective. (Cozijn et al., 2011) conduct both an eye-tracking-during-reading and a self-paced reading experiment to investigate the effect of the connective on subsequent processing. Comparing Dutch sentences with and without the connective "because," they find that the connective speeds up processing of the material directly following it. This facilitation is attributed to easier "propositional integration": the connective helps the reader establish the discourse relation between the two clauses. In sentence-final regions, however, reading times are longer when the clause was preceded by a connective. Cozijn et al. (2011) suggest that this slowdown reflects inferences drawn by readers about the plausibility or validity of the causal relation being expressed. In an eye-tracking study with Dutch secondary school students, van Silfhout et al. (2015) replicate the finding that reading times of clause-initial material are shorter when preceded by a connective, but do not find evidence for a sentence-final slow-down. Similar results on the main facilitative effect of the connective on reading the clause following the connective has not only been found for Dutch (see also Sanders and Noordman, 2000), but also for other languages, such as French (Grisot and Blochowiak, 2017), English (Millis and Just, 1994) and Chinese (Chen et al., 2019; Xu et al., 2018).

2.1 Relation-dependent differences in connective processing

A first research goal of the present study is to examine whether the effect of the connective differs across different discourse relations. Discourse relations cover many different types such as temporal, additive, contrastive or causal (Halliday and Hasan, 1974). Within these categories, more nuanced distinctions can be made. In this paper, we compare a causal relation, result, with two different types of non-causal relations: contrast and concession. A result relation is a causal relation of the order cause-consequence, in which the second clause presents the outcome of the event in the first clause (i.e., P → Q). To illustrate,

in Example 3, repeated as Example 5, the consequence of Paul being late is that he has to run for the bus.

(5)   Paul was late and so he had to run for the bus.

A `concession` relation raises a presupposition of a causal relation that is denied (i.e., P → ¬ Q) (Konig and Siemund, 2000; Webber et al., 2019; Zufferey and Degand, 2024). Consider Example 6. In this example, there is a causal relation between missing the bus and being late, but this consequence of missing the bus is not realised in the `concession` relation described. In other words, the expectation raised in one clause is denied in the other (Webber et al., 2019; Zufferey and Degand, 2024).

(6)   Paul missed his bus. Nevertheless, he arrived on time.

This presupposition of a causal relation is not present in `contrast` relations, which refer to a relation in which the content of the two segments are in semantic opposition (Konig and Siemund, 2000; Webber et al., 2019; Zufferey and Degand, 2024). In Example 4, repeated in 7, there is no presupposed causal relation that Paul being late causes Lea to also be late.

(7)   Paul is usually late, but Lea is always early.

Previous research has shown that some discourse relations are more difficult to process than others. In a self-paced reading study with Dutch speakers, Sanders and Noordman (2000) compared additive (`list`) relations and causal (`problem-solution`) relations. `List` relations involve multiple, independent events or pieces of information (e.g., *"I ate ice cream. I also had some cake."*), while `problem-solution` relations involve a situation that presents a problem followed by a resolution (e.g., *"The street crossing is dangerous. The city council has decided to install a stop sign."*). Sanders and Noordman (2000) found that causal `problem-solution` relations were read more quickly than additive `list` relations. This processing advantage for causally coherent relations is further supported by findings from Chinese. Xu et al. (2018) found that concessive relations were processed more slowly than consequence-cause relations. This aligns with ERP research by Xu et al. (2015), who found that `concession` relations elicited stronger neural responses than `reason` relations. Specifically, sentences containing *although* triggered larger positive waveforms (a P600 effect, approximately 600 ms post-stimulus) compared to those with *because*. Köhne-Fuetterer et al. (2021) found in a visual world paradigm that participants showed lower comprehension on concessive than on causal relations, suggesting that causal relations are easier to comprehend in general.

One explanation for the processing ease of causal relations is the *causality-by-default* hypothesis (Sanders, 2005). This hypothesis proposes that, in the absence of explicit cues to the contrary, readers tend to assume that consecutive discourse segments are causally related, as this interpretation results in the most informative and coherent mental representation. Evidence for this hypothesis comes from continuation studies, where participants produce causal continuations in the majority of cases (Murray, 1997; Simner and Pickering, 2005), and from corpus research showing that causal relations are relatively less likely to be marked with connectives than other relations (see Asr and Demberg, 2012, for results for

English data, and Mendes et al., 2023, for results for Lithuanian, Portuguese and Turkish data, although they do find that some relation types are even less likely to be marked explicitly). This has been taken to suggest that causal coherence can often be inferred without the need for overt marking, making causal connectives less informative, and therefore less necessary, than connectives in other types of relations.

The processing ease of causal relations has also been tested in experimental studies that analyze how the facilitative effect of connectives on discourse processing varies in different relations. Köhne-Fuetterer et al. (2021) found that concessive connectives elicited a larger P600 response than causal connectives, indicating that they require a stronger update of the discourse representation (Köhne-Fuetterer et al., 2021). Furthermore, Kleijn et al. (2019) found that adding causal or contrastive connectives (e.g., *because*, *but*) improved comprehension, while including additive connectives (e.g., *also*) actually impeded it. These findings do not contradict the causality-by-default hypothesis. Although causal connectives facilitated comprehension, this does not rule out a default causal bias; rather, it suggests that explicit marking can still support processing, especially in complex or ambiguous contexts. Crucially, the finding that contrastive connectives yielded a stronger facilitative effect aligns with the hypothesis: contrastive relations deviate from the assumed causal default and are thus more in need of explicit marking. The detrimental effect of additive connectives may reflect their lower informativeness or potential to mislead when not strongly licensed by the discourse context.

In sum, previous research suggests that not all discourse relations are processed equally. Causal relations appear to be cognitively privileged: they are more readily inferred, often left unmarked in natural discourse, and generally processed more easily than non-causal relations. The *causality-by-default* hypothesis accounts for this by proposing that readers assume a causal link between segments unless given cues to interpret the relation otherwise. Accordingly, we may expect larger processing differences between implicit and explicit conditions for non-causal relations, as these relations violate the default assumption and depend more heavily on overt marking to be processed efficiently.

2.2 Cross-linguistic differences in connective processing

A second research goal of the current study is to examine whether the facilitative effect of a connective is different across languages. Although the facilitative effect of connectives has been shown for a variety of languages (see Section 2), there is some evidence that the extent to which readers rely on such lexical cues may differ between languages. For instance, Schwab and Liu (2020) find language-related differences in the facilitative effect of lexical and contextual cues. They investigate a pair of flexible German and English discourse markers, namely *zwar...aber* and *true/sure...but*, as in (8).

(8)   James likes to run [outdoors, Ø]$_{contextual}$. [True, Ø]$_{lexical}$ he has a treadmill in the living room, **but** he often jogs in parks.

In a self-paced reading study, they find that the German connective *aber* ("but") is easier to process when the preceding lexical cue *zwar* ("sure/true") is present: Reading times on the connective *aber* are shorter when the connective is preceded by the lexical cue *zwar* compared to when it is not. They find a similar, albeit delayed, effect in English (it is found on the spillover region in English compared to the connective in German). Schwab and Liu (2020) also include a condition with a contextual cue, which enables readers to predict an upcoming concessive relation based on incoherence in the context. However, this contextual cue only facilitates the processing of the connective in German and not in English. This suggests that English readers rely less on contextual cues than German readers. However, the authors acknowledge that the difference between languages could also be attributed to differences in data acquisition: The German data was collected in-lab, whereas the English data was crowd-sourced.

Contrary to Schwab and Liu (2020), Blumenthal-Dramé (2021) hypothesizes that English readers rely more on contextual cues, whereas German readers make more use of lexical cues for coherence. The degree to which German and English speakers rely on different sources of information (i.e., lexical or contextual) is acribed to typological differences between the two languages under investigation. Specifically, languages differ in the extent to which meaning is encoded in the linguistic signal, also referred to as the analytic-synthetic continuum. Synthetic languages are characterized by heavy inflection, encoding distinctions such as tense, syntactic role, or word class. Examples of synthetic languages include Russian, and, to a lesser extent, German. To illustrate the characteristics of synthetic languages, consider Examples 9 and 10, which are both German:

(9) Du magst deine
    you.2SG.NOM like.2SG your.2SG.FEM.ACC
    Nachbarin.
    neighbour.SG.FEM
    "You like your neighbour."

(10) Ihr mögt eure
    you.2PL.NOM like.2PL your.2PL.FEM.ACC
    Nachbarin.
    neighbour.SG.FEM
    "You like your neighbour."

In these example, the subject pronouns (*du* vs. *ihr*) and verbs (*magst* vs. *mögt*) are morphologically marked for person and number. Additionally, the possessive pronouns (*deine* vs. *eure*) reflect case, number, gender, and agreement with the feminine noun *Nachbarin* ("neighbour"). In contrast, more analytic languages (e.g., English, Mandarin Chinese) typically lack inflectional morphology and have a low morpheme-to-word ratio. Consider the English translation of Examples 9 and 10. Here, neither the subject pronoun nor the verb form reveals whether the addressee is singular or plural, and feminine or male. These distinctions are not morphologically marked in any of the positions, illustrating how analytic languages tend to express grammatical distinctions less overtly than their synthetic counterparts.

These typological differences in linguistic structure have been argued to influence processing strategies. Hawkins (2019) argues

that the representation of a word in English, an analytic language, depends heavily on its surrounding context. Speakers of analytic languages may therefore be more inclined to rely on contextual cues to infer meaning. Returning to the examples above, the English sentence *You like your neighbour* leaves key information underspecified: it does not indicate whether *you* refers to a singular or plural addressee, nor does it specify the gender of the neighbour. Readers must infer these aspects based on context. In contrast, since meaning is often encoded more explicitly in synthetic languages like German, speakers of such languages have to infer less than speakers of analytic languages and may therefore rely more on the linguistic information within a single word. As seen in Example 9, person, number, case, and gender are explicitly marked on the pronouns and noun, reducing the need for contextual inference.

This typological distinction might also have implications for discourse processing. Specifically, it has been suggested that speakers of synthetic languages are more affected by the presence or absence of overt connectives than speakers of analytic languages (cf. Blumenthal-Dramé, 2021). Because synthetic language users are accustomed to extracting meaning from morphosyntactic cues within individual words, they may place greater weight on a connective when interpreting the relation between discourse segments. In contrast, speakers of analytic languages may be more likely to infer the discourse relation from contextual and pragmatic information, regardless of whether a connective is overtly present. In other words, speakers of analytic languages such as English might be able to more easily infer the discourse relation in the absence of a connective due to their reliance on the context.

While direct evidence from processing studies is still lacking, corpus-based findings offer preliminary support for the hypothesis that German speakers may rely more on connectives than English speakers: In parallel translated texts, it has been observed that connectives are frequently added when translating from English to German, and conversely, often omitted when translating from German to English (Becher, 2011; Yung et al., 2023). Some of these shifts may be attributable to translation-specific strategies; nevertheless, there are also broader cross-linguistic differences that could account for the increased number of connectives in German. According to Becher (2011), German discourse conventions place a greater emphasis on overt signaling of discourse relations. As a result, German speakers tend to use more connectives than English speakers and German texts generally contain more connectives to comply with these communicative norms.

The ubiquitous presence of connectives in German may lead German speakers to rely on them more during real-time language processing than English speakers. If so, we would expect that the absence of an explicit connective would pose greater processing difficulty for German readers than for English readers. In contrast, English speakers, who are more frequently exposed to unmarked causal and contrastive relations, may be more accustomed to inferring discourse coherence without overt markers, resulting in a smaller processing difference between implicit and explicit conditions. Thus, cross-linguistic differences in connective usage thus provide a potential source of variation in how discourse relations are processed across languages.

2.3 The present study

In the current study we present two self-paced reading experiments examining the effect of the connective on subsequent processing, focusing on English and German. Words in English, an analytic language, encode less information than in German, a synthetic language. Although these languages are not at the extreme ends of the analytic-synthetic continuum, they differ considerably in the extent to which meaning is encoded within a single word or is dependent on its contextual representation (cf. Hawkins, 2019). Experiment 1 compares the effect of the connectives *so/deshalb* and *but/aber* on the reading times of result and contrast relations. In a similar vein, Experiment 2 compares the effect of the connectives *therefore/daher/deshalb* and *still/trotzdem/dennoch* on the reading times of result and concession relations.

We test the *causality-by-default hypothesis* (Sanders, 2005), the reader's preference for relating text segments causally. Causal relations are argued to be cognitively privileged because they align with general inferential mechanisms that humans use to make sense of events. If such a default causal inference operates, readers can readily establish causal coherence even in the absence of an explicit connective. Consequently, while an explicit causal marker may still facilitate processing, its additional benefit should be relatively small compared to that of connectives for other types of relations. In contrast, for negative relations such as concession or contrast, where no default causal inference applies, connectives are expected to play a greater role in guiding interpretation and should therefore produce a stronger facilitative effect. In line with previous work (Murray, 1997; Köhne-Fuetterer et al., 2021), we investigate whether the effect of relation marking is smaller in result relations than in other relations:

H1 The facilitative effect of the connective on reading is smaller in result relations than in other relations (i.e., contrast, concession).

This predicted effect is illustrated in Figure 1a.

Beyond this cognitive-level prediction, we also examine whether typological differences influence the degree to which readers rely on linguistic versus contextual information. Prior research hypothesized that readers of analytic languages (e.g., English) rely more on contextual inference, whereas readers of synthetic languages (e.g., German) rely more on overt linguistic marking (Blumenthal-Dramé, 2021). If so, the causality-by-default tendency (i.e., reliance on inferential coherence rather than explicit marking) should be stronger in English than in German. We investigate whether the facilitative effect of the connective on reading is indeed smaller in English, an analytic language, than in German, a synthetic language (cf. Figure 1b):

H2 The facilitative effect of the connective on reading is smaller in English than in German.

Finally, if English readers rely more on default causal interpretation, the relation-dependent modulation of connective effects predicted by H1 should be larger in English than in German. This is illustrated in Figure 1c. In other words, there should also be a three-way interaction between relation marking, language and relation, such that language-specific reliance on inferential

cues should interact with the cognitive-level preference for causal interpretation. More specifically, we hypothesize that:

H3 The interaction between relation marking and relation is larger in English than in German.

The present study builds on Blumenthal-Dramé (2021), which originally reported processing differences between implicit and explicit discourse relations in German and English: German readers benefited more from the presence of connectives than English readers, and concessive connectives provided greater processing advantages than causal ones in both languages. Those findings initially motivated our research questions and design: Experiment 1 constitutes a conceptual replication of the original study, and Experiment 2 a closer, more direct replication. However, the article was retracted after completion of our replications due to a statistical error in the original analyses (see The Editors of Discourse Processes, 2024). We therefore cannot treat Blumenthal-Dramé (2021)'s results as confirmatory evidence, since they can no longer be considered reliable, but the design of the original study did provide a starting point for identifying relevant discourse conditions and target structures. Several design choices in the current work were motivated by the original study; where appropriate, these will be explicitly acknowledged in the methodological sections that follow.

3 Experiment 1

In this first experiment, we compare the influence of the presence of a connective in result and contrast relations, testing native speakers of English and German.
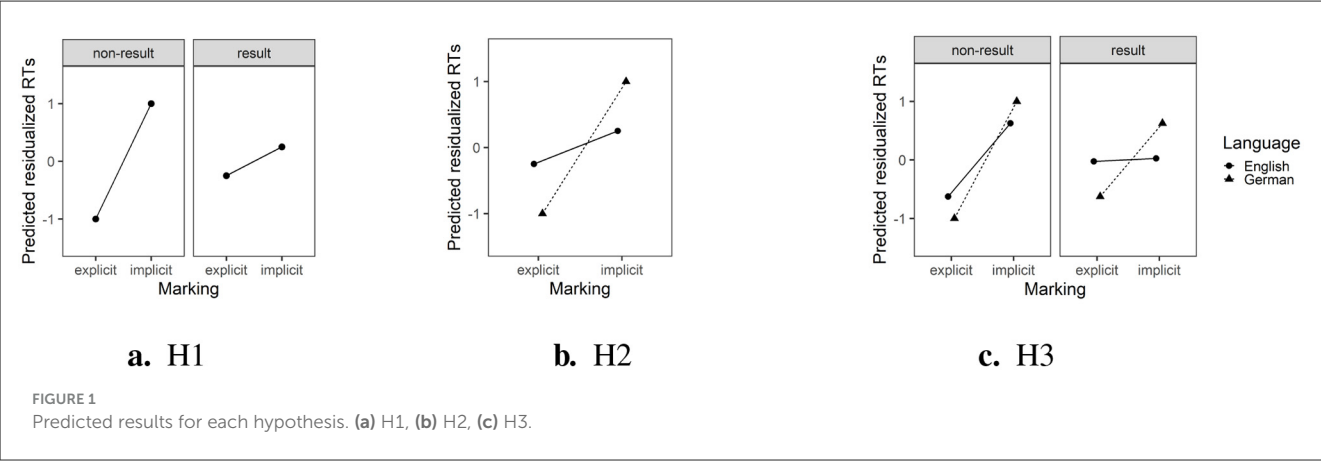
3.1 Methodology

3.1.1 Participants

In total, 220 participants were recruited via Prolific, in parity with Blumenthal-Dramé (2021). Half of them were native speakers of English who were based in the United States, and the other half were native speakers of German and were living in Germany. None of the participants reported any known language-related disorders. After excluding some participants from further data analysis (see below), 102 English (mean age: 37; female: 49) and 99 German (mean age: 35; female: 39) participants remained.

3.1.2 Materials

The items followed a 2×2×2 design, crossing relation type (result vs. contrast), relation marking (explicit vs. implicit), and language (English vs. German). Some of the materials were adapted from Blumenthal-Dramé (2021). Example items for each condition can be found in Table 1.

Relation type was manipulated between items: each item instantiated either a target result relation ($n = 20$) or target contrast relation ($n = 16$). These target relations were embedded in a communicative context. Each item began with two introductory sentences to establish the context and introduce the

FIGURE 1
Predicted results for each hypothesis. **(a)** H1, **(b)** H2, **(c)** H3.

protagonists and events. This was followed by direct speech from a protagonist, which contained the critical discourse relation and a spillover region.

Relation marking (explicit vs. implicit) was manipulated within items. Following Blumenthal-Dramé (2021), the implicit condition used the coordinating conjunction *and* (or *und* in German) without an explicit connective that marks the intended result or contrast relation. The inclusion of *and/und* was done to prevent the use of a full stop, which could trigger wrap-up processes confounding effects of the connective. *And* is compatible with many types of discourse relations; it has been found to co-occur with relations such as specification, consequence, and concession (Crible, 2017; Spooren, 1997; Webber et al., 2019). While the stimuli are therefore not fully implicit (due to the presence of *and/und*), the target relation remains pragmatically implicit. We will return to this in the discussion (Section 3.3).

The explicit condition was created by the inclusion of a result connective (English *so* or German *deshalb*) or a contrast connective (English *but* or German *aber*), depending on the condition. In result conditions, the result connective was added to the additive conjunction (*and/und*) to reflect natural usage, thereby ensuring structural comparability between the implicit and explicit conditions. In contrast conditions, the contrastive connective replaced the conjunction to maintain grammaticality and naturalness.

Language was also a within-items manipulation: each item had both an English and a German version, which were direct translations of each other. They were constructed in collaboration with native speakers of German and English, who translated the materials and checked for fluency.

The target region, presented in bold in Table 1, is the region in which the relation with the preceding sentence becomes clear. In the result relations, this region presents the consequence of the cause in the preceding clause. In the contrast relations, the information in the target region contrasts that in the preceding clause.[2] The target region is followed by a spill-over region (underlined), consisting of the connective 'and' and an auxiliary verb phrase introducing the final clause. This was done to prevent

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2   We use a region-by-region self-paced reading paradigm, to ensure a single reading time for all critical words in a sentence.

TABLE 1 Example stimuli.

Language	Result
English	Finn had a date | with his girlfriend Daisy | at a new restaurant | last week. | His brother asked him | whether | the food was good. | Finn answered, | "Not really. | Daisy | ate spoiled fish | and {∅, so} | **she got stomach cramps** | <u>and had to</u> | throw up."
German	Finn hatte letzte Woche | ein Date | mit seiner Freundin Dagmar | in einem neuen Restaurant. | Sein Bruder fragte ihn, | ob | das Essen gut war. | Finn antwortete: | "Nicht wirklich. | Dagmar | aß verdorbenen Fisch | und hat {∅, deshalb} | **Magenkrämpfe bekommen** | <u>und musste</u> | sich übergeben."
	contrast
English	Khalil | was telling Eduardo | that he and his girlfriend | disagree so often. | He asked | if Eduardo | always sees eye to eye | with his girlfriend. | Eduardo replied, | "I don't mind | a white lie | {and, but} Jodie | **is always honest** | <u>and was</u> | shocked | when she | heard me lie | the other day."
German	Khalil | erzählte Mattheo, | dass er und seine Freundin | sich so oft streiten. | Er fragte, | ob Mattheo | immer auf Augenhöhe | mit seiner Freundin sei. | Mattheo antwortete: | "Ich habe nichts | gegen eine Notlüge | {und, aber} Judith | **ist immer ehrlich** | <u>und war</u> | schockiert, | als sie | mich letztens | lügen hörte."

The implicit condition had either no connective or the conjunction "and"/"und," the explicit contained the connectives "so"/"*deshalb*"; these variants are displayed here in curly braces. The critical region is highlighted in bold, the spillover is underlined. Chunk breaks are indicated with |.

any wrap-up effects on the target region triggered by punctuation in this region. Since no material can follow the verb in German, this had to be another clause. To make the repetition of 'and' more natural, the target relation was embedded in a conversational context.

Since the result connective follows the finite verb in German, the German version always contained an auxiliary verb (e.g., by using present perfect tense). The auxiliary verb was included in the pre-critical region, as the connective follows the auxiliary in German. Although the syntactic structure of the target region in the result relations is different across languages, this does not confound our findings, since we are interested in the interaction of language with relation marking, rather than a main

effect of language. Note that within each language, the syntactic structure is the same across relation marking.

The experimental items were interspersed with 31 fillers from an unrelated experiment, see 11 for an example. These filler items consisted of a similar structure as the experimental items, but did not contain `result` or `contrast` connectives.

(11)   Ruben is very concerned for the environment. His uncle asked why he cared so much. Ruben said, "There are multiple signs that the environment is in grave danger. First, sea ice is melting and retreating at a rapid pace. Second, we can see that high temperature extremes are increasing. It scares me!"

3.1.3 Procedure

The self-paced reading experiment was hosted on PCIbex (Zehr and Schwarz, 2018). Participants first provided informed consent and read the instructions. They were asked to read in their natural pace. After completing three practice trials, participants proceeded with the actual experiment. The items were distributed across different lists, such that every participant saw each item only once. The experimental items were interspersed with 31 fillers from an unrelated experiment, resulting in 67 items per list. The order of the trials was randomized. Half-way during the experiment, participants were given the option to take a short break. They could then proceed with the experiment by pressing a button. The study took between 15–20 min and participants received £3.

Every trial started with a fixation cross. After pressing the space bar, a series of horizontal lines was presented (left-justified text). Each line reflected a chunk of words as indicated in Table 1, with the length of the lines corresponding to the number of characters in that chunk. Pressing the space bar revealed the content of the next chunk and replaced the previous chunk with lines. Almost a quarter of the items (n=16) was followed by a verification statement. These statements were either true or false, with respect to the item just seen. For the experimental items, these statements were about the information in the target discourse relation. The statement used for the example `result` item in Table 1 is provided in (12). For the filler items, these statements also questioned information at the beginning and end of the item.

(12)   Daisy got stomach cramps because she ate spoiled fish.

Participants could respond to the verification questions using the `f` and `j` key, which would immediately take them to the next trial. No feedback was provided on the verification statements.

3.1.4 Analysis procedure

Data from participants ($n = 18$) who scored less than 70% on the comprehension questions as well as from one participant who reported that they noticed typos was removed. After data collection, a few grammatical inconsistencies were discovered in the items. We therefore excluded all reading time data from four English `result` items and one English `contrast` relation, as well as data from the spill-over region from a German `result` item from the analysis. Furthermore, we removed data from items ($n = 13$) on which the participant spent more than a minute, as this indicates that they

may have taken a break. We also removed reading times lower than 100 ms or above 2,500 ms as well as log-transformed reading time values 2.5 SD away from the participant's mean.

To account for variability in reading times that is unrelated to the experimental manipulations, we controlled for four covariates: (i) region position (i.e., number of preceding chunks), (ii) trial number (i.e., number of preceding trials), (iii) region length (i.e., number of characters), and (iv) the main effect of language (English vs. German), along with its interactions with the other covariates. These variables can systematically influence reading times. For example, later regions and trials often yield faster reading times due to learning or adaptation (Fine et al., 2013), longer chunks naturally take longer to read, and language differences can interact with these general effects. We therefore residualized the reading times: we estimated the effects of these covariates only on the filler items, which were structurally similar but not affected by the experimental manipulations. This approach ensures that the estimated effects of position, length, trial, and language are uninfluenced by the critical manipulations, allowing us to partial them out more cleanly. The approach of residualizing on fillers has been taken in previous studies as well (e.g., Fine and Jaeger, 2016; Huang et al., 2024; Patra et al., 2023; Van Dyke and Lewis, 2003).

Specifically, we fit a baseline linear mixed-effects model to the log-transformed reading times of the filler regions (excluding the first and last region of each item). The model included fixed effects for trial number, region position, and region length, as well as their interactions with language. Random intercepts and slopes were included by subject.[3] We then used the parameter estimates from this model to predict reading times for the experimental regions. The difference between observed and predicted reading times, henceforth diffRT, reflects reading time variance above and beyond what is expected due to general processing factors. We then used these diffRT values as the dependent measure in our main analyses, regressing them on the experimental conditions of interest.

German, implicit, `contrast` were coded as –1 and English, explicit and `result` as 1. Continuous predictors were centered and scaled. We aimed for a maximal random effect structure, but removed intercept-slope correlations as well as those random effects that explained the least variance in a step-wise manner until convergence was reached.

Analyses were conducted using the package `lme4` (Bates and Sarkar, 2007) in R (R Core Team, 2022) using RStudio (RStudio Team, 2020). Significance of the predictors was evaluated using `lmerTest` (Kuznetsova et al., 2017) and *post-hoc* analyses of interactions were conducted with `emmeans` (Lenth, 2024). Visualizations were made using `ggplot2` (Wickham, 2016), `effects` (Fox and Hong, 2009) and `xtable` (Dahl et al., 2019).
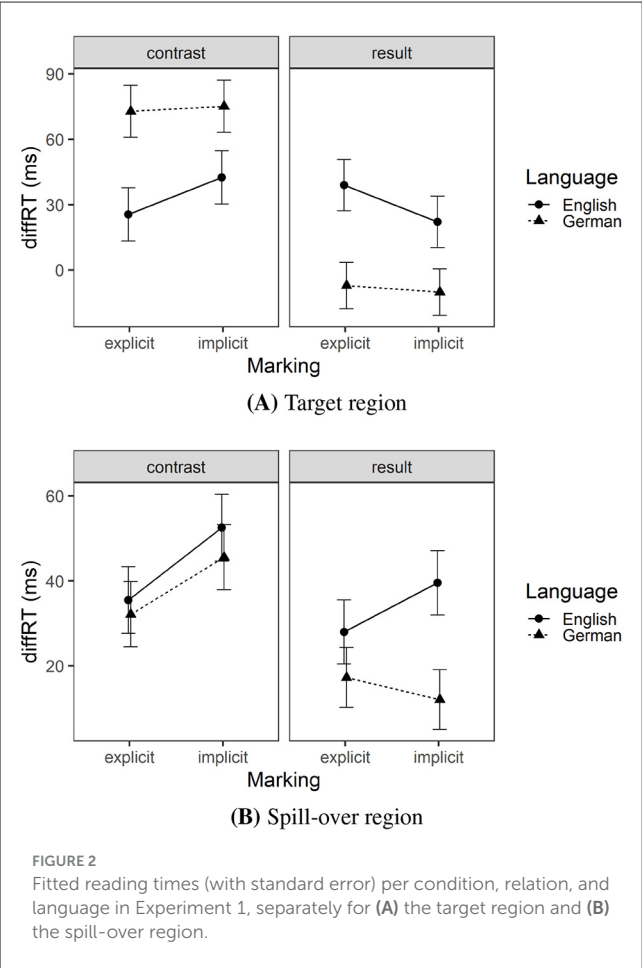
3.2 Results

The output of the model can be found in Table 2 below and the fitted reading times (diffRT) in each condition are plotted in Figure 2. We find a main effect of relation marking on reading

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3   log(rt) ~ trial*language + position*language + length*language + (1 + trial + length || subject)

TABLE 2 Model output of Experiment 1 for the target and spill-over region.

Fixed effect	Target				Spill-over			
	β	SE	t	p-value	β	SE	t	p-value
(Intercept)	32.47	5.64	5.76	**<0.001**	32.81	3.56	9.22	**<0.001**
Marking	0.08	3.11	0.03	0.98	−4.61	2.20	−2.10	**0.04**
Relation	−21.54	5.87	−3.67	**<0.001**	−8.61	3.61	−2.38	**0.01**
Language	−0.23	4.10	−0.06	0.96	6.06	2.68	2.26	**0.01**
Marking:relation	4.89	3.11	1.57	0.13	3.01	2.20	1.37	0.11
Marking:language	−0.10	2.69	−0.04	0.97	−2.55	1.83	−1.39	0.27
Relation:language	19.78	4.42	4.47	**<0.001**	3.49	2.75	1.27	0.16
Mark:rel:lang	3.57	2.69	1.33	0.25	−1.65	1.83	−0.90	0.49
Model formula (target): `diffRT~mark*rel*lang+(1+mark*lang||item)+(0+rel|subj)`								
Model formula (spill-over): `diffRT~mark*rel*lang+(1+mark+lang||item)+(0+rel|subj)`								

Values printed in bold are significant.

FIGURE 2
Fitted reading times (with standard error) per condition, relation, and language in Experiment 1, separately for **(A)** the target region and **(B)** the spill-over region.

times only in the spill-over region. In this region, relations that are marked with a connective are read faster than those that are not, in line with findings from earlier research. The hypothesized interaction between relation marking and language is not significant in either of the regions, nor is the interaction

between relation and marking, or their three-way interaction with language.

The results show a main effect of relation: as expected, `contrast` relations were read slower than `result` relations in both regions. There is also a significant interaction between relation and language in the target region, suggesting that the effect of relation is larger in German than in English in this region. This effect could be due to the differences in clause structure: the target region in the German `result` relations was preceded by an auxiliary verb, which might have facilitated processing of the target region. Such an auxiliary verb was not present for the German `contrast` relations, nor in either conditions of the English items. A *post-hoc* analysis reveals that the main effect of relation is significant in German ($\beta = 82.64$, $p <0.001$), but not in English ($\beta = 3.53$, $p = 0.82$).

3.3 Discussion

This study aimed to examine whether the facilitative effect of connectives on on-line processing differs across languages (English vs. German) and relation types (`result` vs. `contrast`). Previous research has repeatedly shown that the presence of a connective facilitates processing, especially in clause-initial regions. The present study shows an effect of relation marking in the spill-over region only. Crucially, we did not find any evidence that the effect of relation marking differs per language or relation type in either region.

In line with previous research, `contrast` relations were read slower than `result` relations. The strength of this effect was different across languages, but this may have been confounded by the clause structure of the German `result` relations. Reading times were shortest in these German `result` items, which was the only condition in which the target region was preceded by an auxiliary verb.

Note that, in line with Blumenthal-Dramé (2021), the stimuli in the implicit condition all contain the word *and* (or *und*) and were therefore not fully implicit. *And* is an underspecified connective

that co-occurs with many different relation types and does not explicitly signal the `result` or `contrast/concession` relations, it does provide some information. Importantly, it occurs more often within `result` than in `contrast` and `concession` relations (Das and Taboada, 2018; Webber et al., 2019) and appears to be more compatible with relations of `consequence` than of `contrast` in experimental studies (Crible and Demberg, 2020). While the presence of *and/und* means that our implicit condition was not fully unmarked, this design choice ensured that potential effects could be attributed to the type of connective rather than to sentence boundary or wrap-up effects (a confound observed in prior studies, e.g., Millis and Just, 1994). Moreover, using an underspecified connective like *and* provides a test of the facilitative power of explicit markers, since any observed differences emerge despite both conditions being locally coherent.

The effect of the connective was hypothesized to emerge in the target region, as this is the disambiguating region of the sentence. Previous research has shown larger effects of the connective in early clause regions rather than in final ones (Cozijn et al., 2011; van Silfhout et al., 2015). While delayed effects are not uncommon in self-paced reading paradigms, we nevertheless expected the connective to influence reading times in the target region itself. This expectation was based on earlier findings showing immediate effects of connectives in similar paradigms (Cozijn et al., 2011), as well as on the chunked design of the present study, which may reduce delayed effects. However, in our data, the presence of a connective facilitated reading only in the spill-over region, when it was clear that the target clause had concluded. This finding differs from some prior studies, which did not consistently report facilitation effects in clause-final or post-clausal regions. One possible reason for this discrepancy is the absence of a full stop in our spill-over region. Prior studies often included punctuation after the clause boundary, potentially introducing wrap-up effects that could inflate reading times and obscure any facilitative impact of the connective.[4]

Instead, the spill-over region in this study introduced a third clause with the conjunction *and* followed by an auxiliary verb. This triadic clause structure might have surprised readers, especially in the implicit condition when all three clauses are connected with *and*. This could also explain why the spill-over region was read more slowly in the absence of a connective marking the `result` or `contrast` relations. Importantly, we do not expect this clause structure to have confounded our hypotheses about the interaction with language or relation. The syntactic structure was held constant across languages and relation types, and critically, the structure of the third clause was not yet known to the reader during the target region. Furthermore, the relation was embedded in a reported speech context to mitigate its unnaturalness in the triadic clause configuration. Nevertheless, it remains unclear whether the faster

reading times on the spill-over region in the explicit condition can be attributed to a facilitating effect of the connective.

In addition, syntactic differences between the `result` and `contrast` relations may have served as an additional cue for the `contrast` relation. In particular, the `contrast`, but not the `result` relations, often contained parallel syntactic structure and a change in subject between the first and second argument in the `contrast`. These structural cues may have functioned as implicit signals of contrast, thereby reducing readers' reliance on the explicit connective. As a result, the expected interaction between relation marking and relation type could have been attenuated in the `contrast` condition. Supporting this idea, Crible and Pickering (2020) found that the effect of explicit contrastive marking (e.g., "and" vs. "but") is smaller when the two clauses share parallel structure. However, it is worth noting that Crible and Pickering (2020)'s effect was observed in a task that explicitly required participants to disambiguate the discourse relation, which is something participants in the present study were not asked to do. It is therefore unlikely that discourse relations in our study were processed at the same depth. Another factor that may have influenced processing is punctuation. In standard usage, connectives like *but* and *aber* are typically preceded by a comma, which was intentionally omitted in our stimuli to maintain uniformity across conditions. This absence of a comma may have disrupted readers' expectations in the `contrast` condition, potentially increasing reading times in the explicit connective condition. Such an effect could further obscure any interaction between relation type and relation marking.

We note that all of these factors might have influenced the effect of the connective in our target region, as well as its interaction with language and relation. We therefore conduct another experiment to test our hypotheses with a modified design, which is presented below.

4 Experiment 2

We test the hypotheses presented in Section 2.3 in a second experiment, using a word-by-word self-paced reading paradigm with some methodological changes. In particular, we present participants with longer, more salient connectives, less context and a different non-causal relation: `concession`. This relation might be more difficult to process than `contrast` relations, since it requires readers to infer the presupposed causal relation that is denied. As a result, there is possibly more room for the connective to facilitate reading in this relation type. Here, we directly follow the design of Blumenthal-Dramé (2021).

4.1 Methodology

4.1.1 Participants

A total of 116 native speakers of English (mean age: 39, 56 male) and 143 native speakers of German (mean age: 36, 65 male) participated in the experiment. They were recruited from Prolific. Data from participants ($n = 7$) who failed to answer less than 80% of the comprehension questions correctly were excluded from further analysis.

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4   Another difference with previous studies is that these studies often use longer connectives or even more salient cue phrases (Cozijn et al., 2011; Sanders and Noordman, 2000). With the exception of German "*deshalb,*" In contrast, our study employed short, natural connectives suited for a speech-like context—such as (*so, and, but, aber*). With the exception of the longer German connective *deshalb*, these were all between two and four letters in length.

4.1.2 Materials

Similarly to Experiment 1, the materials for Experiment 2 followed a 2×2×2 design: relation type (result vs. concession), relation marking (explicit vs. implicit), and language (English vs. German). The items consist of two coordinating clauses, connected by "and" (German "und"). Stimuli were taken from Blumenthal-Dramé (2021) with minimal modifications.[5] As in the original study, the materials consist of 44 English items and 32 German items. Example stimuli can be found in Table 3.

The second clause presented either the consequence of the first clause (i.e., result) or a violation of an expectation raised in the first clause (concession). This was achieved by manipulating the first clause. As a result, the second clause of each item was identical across conditions within each language. This second clause contained the target region, which was used for further analysis. Following Blumenthal-Dramé (2021), the target region consisted of a critical word (a lexical item at which the relation could be established), its spillover word, and the final word of the sentence.

With respect to relation marking, in the explicit condition, result relations are marked by the connective "therefore" and concession relations are expressed with "still" in English. As per the original German stimuli, two different connectives are included per relation: "trotzdem"/"dennoch" (still) for the concessive and "deshalb"/"daher" (therefore) for the result relations. We add each connective to half of the stimuli and therefore have 16 items with one connective, and 16 with the other. Participants are shown equal numbers of stimuli with each of the different connectives, i.e., 50% of the explicit concessive sentences shown to a participant contain "dennoch," the other 50% contain "trotzdem." No connective (except the coordinating conjunction "and") was present in the implicit condition (cf. Experiment 1).

In addition to these experimental items, 256 filler sentences were created in English and 80 in German.[6] The English study contained more experimental and filler items than the German study because this was also the case in Blumenthal-Dramé (2021) and we wanted to keep the structure as similar as possible. The fillers do differ to the original study, but they are similar in syntactic structure and, crucially, they do not contain causal or concessive connectives (examples of filler items: *Alice twisted a silk scarf round her neck.* / *Tina hat die Zeitung gelesen.*).

For about a quarter of the sentences (both filler and critical), a comprehension question with two alternative answer options was created. Example 13 shows the comprehension question for the English concession item in Table 3.

(13)   What did Christopher invest in?
         (i) new equipment
         (ii) new technology

TABLE 3   Example stimuli.

Language	Result
English	Luis won a prize and (∅/*therefore*) **invested** <u>in</u> new equipment.
German	Anita war hochbegabt und übersprang (∅/*daher*/*deshalb*) zwei **Klassen** <u>auf</u> der Grundschule.
	'Anita was very gifted and (*therefore*) moved up two **years** <u>at</u> primary school.'
	concession
English	Christopher had no money and (∅/*still*) **invested** <u>in</u> new equipment.
German	Anita hatte eine Lernschwäche und übersprang (∅/*trotzdem*/*dennoch*) zwei **Klassen** <u>auf</u> der Grundschule.
	'Anita had a learning disability and (*still*) moved up two **years** <u>at</u> primary school.'

The explicit condition contained the connective, printed in *italics* here, the implicit did not. The critical word is highlighted in bold, the spillover is underlined. The stimuli are from Blumenthal-Dramé (2021).

4.1.3 Procedure

A word-by-word moving window self-paced reading task was implemented using Ibex (Drummond, 2007). Participants were instructed to read in their natural pace with the aim of understanding the sentences fully. After a short practice phase, participants read a total of 96 sentences in German (16 experimental items) and 344 sentences (88 experimental items) in English.[7] The order of the trials was randomized for each participant. Each trial was displayed in a similar way to Experiment 1 (cf. Section 3.1.3), except individual words were displayed (not chunks), and there was no fixation cross at the start of every trial (underscores for each word in the sentence were displayed immediately). Participants responded to the verification questions using the keys 1 or 2.

The German items were distributed across four different lists such that each participant only saw each item once, with an equal number of items from each condition (relation, presence of connective). Following the original study (Blumenthal-Dramé, 2021), the English items were distributed across two different lists, where each list contained an equal number of items from each condition (relation, presence of connective), but contained the target clause twice (once in a concession and once in a result relation). The German study took on average 20 min to complete and the English study around 45 min. Participants were compensated at least £9 per hour.

4.1.4 Analysis procedure

The analysis procedure was similar to that reported in Experiment 1. We removed reading times below 100 ms and above 2,000 ms, as well as log-transformed RTs that were more than 2.5 SD away from the participant's mean. We fit a baseline model

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5   We correct two typos and changed the wording of a few items (*n* = 4) in German to make them clearer.

6   The original study used 96 fillers in German. 16 of the German fillers in the current experiment were similar to the experimental items, except that the coordinating conjunction 'and' was replaced by a comma for a related experiment that is not reported here.

7   Under a rapid expectation adaptation account (Fine et al., 2013), the smaller number of fillers in German would be expected to mitigate the effect. However, we would expect the effect of relation marking to be larger in German, thus the number of fillers biases against our hypothesis.

on the filler data[8] to estimate the effects of the covariates and predict reading times for the experimental items.[9] We calculate the difference between the predicted and observed reading times (diffRT). We then summed these diffRTs for each word of the target region in each item. This was done to remain agnostic about the position of the effect, while maximizing power. [10] As in Experiment 1, all continuous variables were scaled and centered. The binary predictors were again coded such that German, implicit, `concession` were −1 and their counterparts 1.

4.2 Results

The predicted residualized reading times are plotted in Figure 3. The model estimates, found in Table 4, show a significant main effect of marking, as well as an interaction between marking and relation type: in line with H1, the facilitating effect of a connective is larger in `concession` relations than in `result` relations. More specifically, a *post-hoc* analysis revealed that the effect of relation marking is significant in `concession` relations (β = 21.90, SE = 7.16, p < 0.01), but not in `result` relations (β = −5.14, SE = 7.07, p = 0.47). In turn, this interaction between marking and relation type is dependent on language, as shown by the significant three-way interaction between marking, type and language. However, the direction of this interaction is opposite from what was hypothesized. The facilitating effect of connectives in `concession` relations specifically was expected to be larger in English than in German (cf. H3). Instead, a *post-hoc* analysis reveals that the interaction between relation marking and relation type is significant in German (β = 47.3, SE = 17.94, p < 0.01), but not in English (β = 6.8, SE = 8.44, p = 0.42). In other words, we find evidence that the effect of the presence of a connective on reading times is dependent on relation type in German, but do not find evidence for this effect in English.

The German stimuli included two different connectives for each relation; *"dennoch," "trotzdem"* for `concessive` and *"daher," "deshalb"* for `result`. In a follow-up analysis on the German subset of the data, we found that the two connectives did not significantly influence reading times for the `result` relations (p =0.66) or the `concession` relations (p = 0.12).

Since Experiment 1 did not provide evidence for the hypothesis that the facilitating effect of a connective is language-dependent, we set out to test our hypotheses with a different design in Experiment 2. We included longer, more salient connectives and simpler items with less context. With this design, the results showed an interaction of relation marking with relation type, such that
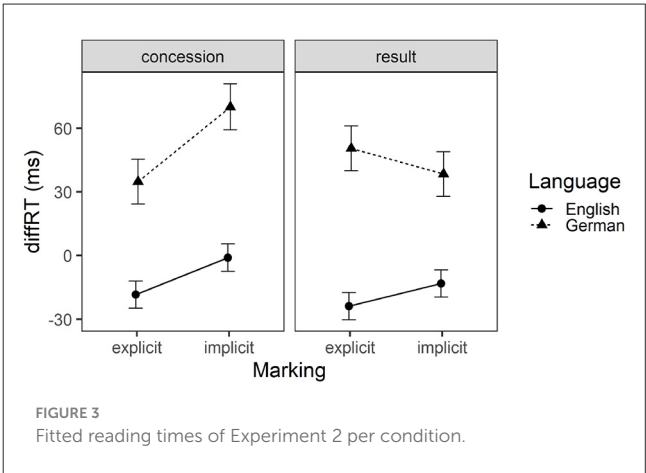

FIGURE 3
Fitted reading times of Experiment 2 per condition.

TABLE 4 Model output for Experiment 2.

Fixed effect	β	SE	t	p
(Intercept)	17.15	4.36	3.94	**<0.001**
Marking	−6.41	2.60	−2.47	**0.01**
Relation	−4.19	2.55	−1.64	0.10
Language	−31.25	4.36	−7.17	**<0.001**
Marking:relation	6.76	2.48	2.73	**<0.01**
Marking:language	−0.61	2.60	−0.24	0.81
Relation:language	−0.21	2.55	−0.08	0.94
Marking:rel:lang	−5.06	2.48	−2.04	**0.04**
Model formula: rt~mark*rel*lang+(1+rel||item)+(0+mark|subj)				

connectives facilitated reading in `concession` relations but not in `result` relations.

Language-related differences in connective processing were expected based on the hypothesis that speakers of synthetic languages, such as German, rely more on linguistic information (e.g., connectives) to infer relations than speakers of analytic languages, since lexical items provide less information in these latter languages. Rather, speakers of analytic languages, like English, were hypothesized to rely more on contextual cues or on default strategies, such as inferring causality by default. However, the hypothesized interaction between relation marking and language was not found: connectives did not facilitate reading more in German than in English. Contrary to this hypothesis, we find that relation-dependent differences in the effect of the connective are larger in German than in English. This suggests that other language-related factors might play a role in the relation-dependent effect of the connective.

5 General discussion

This study set out to examine whether the facilitative effect of the connective is not only relation-dependent, but also language-dependent. More specifically, we aimed to examine whether connectives speed up reading less in `result` relations

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8   We excluded the first, but not the last word of the filler items, since the experimental items also contain reading times of the item-final word.

9   Model formula: `log(rt) ~ trial*language + wordpos*language + length*language + (1 + trial || subj)`

10   An alternative is to build separate regression models for each region, but this introduces more comparisons, increasing the likelihood of a Type I error or significantly decreasing power by correcting for these comparisons. For the interested reader, a word-by-word analysis of the target region is presented in Appendix 1.

TABLE 5 Overview of results.

Fixed effect	Exp. 1		Exp. 2
	Target	Spill	
Marking	-	✓	✓
Relation	✓	✓	-
Language	-	✓	✓
Marking:relation	-	-	✓
Marking:language	-	-	-
Relation:language	✓	-	-
Marking:relation:language	-	-	✓

✓ indicates that a significant effect was found.

compared to other relations, as assumed by the causality-by-default hypothesis (Sanders, 2005). In addition, we hypothesized that the effect of the connective is larger in German than in English, due to typological differences between the two languages (Blumenthal-Dramé, 2021). For this purpose, we presented two self-paced reading experiments. In Experiment 2, we indeed find that the effect of relation marking is larger in concession relations (H1). However, in neither of these experiments did we find a significant interaction between relation marking and language (H2). Interestingly, we find that the relation-dependent effect of marking is larger in German than in English, contrary to H3. An overview of the findings for each of the effects can be found in Table 5. Below, we discuss their theoretical implications as well as how the methodological differences between the studies might influence the findings.

5.1 The effects of relation marking and relation type

The main effect of interest is the influence of connectives on reading times. Connectives have been shown to facilitate processing for a variety of languages and relations, although this effect differs across relations and the time-course of the sentence (Millis and Just, 1994; Cozijn et al., 2011; van Silfhout et al., 2015). Our findings add to this literature by showing that the facilitative effect of connectives is not uniform, but instead interacts systematically with the type of discourse relation being processed. In Experiment 2, we observed that connectives facilitated processing more reliably for concession than for result relations: reading times were consistently shorter for concession relations when a connective was present, even at the sentence-final position. These patterns are in line with results from prior studies showing that connectives have different effects on processing and comprehension of different types of relations (Kleijn et al., 2019; Köhne-Fuetterer et al., 2021; Xu et al., 2018). In Experiment 1, we did not find an interaction between marking and relation type. We did find an effect of relation marking in the spill-over region, but the effect was confounded with possible effects of clause structure.

The findings reported in the current studies align with the *causality-by-default* hypothesis (Sanders, 2005), which states

that readers default to a causal interpretation when processing unmarked discourse relations, providing a processing benefit for causal relations. If readers assume a causal relation by default, an explicit causal connective such as *therefore* offers less additional information and is thus less likely to facilitate processing. In contrast, connectives marking non-causal relations such as concession relations can help readers update their assumption about the upcoming relation, and so the connective can provide more additional information about the content of the upcoming clause. This hypothesis provides a plausible explanation for why we found a robust facilitative effect of connectives for concession relations but not for result relations.

However, a further prediction of the *causality-by-default* hypothesis is that causal relations such as result should generally be processed more easily than non-causal relations (i.e., we should observe a significant main effect of relation). Although Experiment 1 showed faster reading times for result than contrast relations, this may have been confounded by syntactic differences. In Experiment 2, we did not find a significant main effect of relation. This weakens the broader claim that causal relations are inherently easier to process and suggests that other factors, such as relational complexity, syntactic cues and position in the sentence, may moderate this effect.

Relating to relational complexity, note that concessive relations are considered cognitively demanding because they require comprehenders to recognize an expected outcome ("X should lead to Y...") and integrate an alternative outcome that violates it ("...yet not Y") (Konig and Siemund, 2000; Zufferey and Degand, 2024). This introduces additional inferential steps and may increase processing time even when a connective is present. Moreover, causal, concessive and contrastive relation types have been distinguished from one another based on their cognitive complexity and the continuity of the relations. Specifically, the negative polarity of both concessive and contrastive relations has been linked to greater cognitive complexity compared to the positive polarity of causal or additive relations (Hoek et al., 2017), and the discontinuous nature of concessive and contrastive relations has been argued to make them more difficult to process compared to the continuous causal relations (Das and Egg, 2023). From this perspective, the stronger facilitative effect of connectives for concessive relations may not only reflect the absence of a default causal expectation, but also the function of connectives in supporting integration for more complex relations. This account could also explain why no difference was found between result and contrast relations, even though a difference was found between result and concession relations: because they are negative additive relations, contrast relations are cognitively less complex than concession relations, which are negative causal relations (Hoek et al., 2017). Incorporating relational complexity or continuity into models of discourse processing could thus provide a more nuanced account that complements the causality-by-default hypothesis.

The position of the critical region also appears to modulate the effect of connectives. Previous research has shown that connectives mainly facilitate reading directly following the connective, where they can guide expectation-building (Cozijn et al., 2011; van Silfhout et al., 2015). In Experiment 2, where the target region

was sentence-final, we did not observe a general facilitative effect of connectives for result relations (see also Appendix 1). A possible explanation for this is that, instead of facilitating processing, the connective triggers a time-consuming, retrospective inference. Such elaborative reasoning could momentarily increase processing load, consistent with Kleijn et al. (2019), who found that additive connectives sometimes impeded comprehension by eliciting additional inferencing. This interpretation also aligns with the *causality-by-default* hypothesis: when causal relations are easily inferred, explicit marking may not further facilitate online processing.

For concession relations, we do see a facilitating effect of the connective. Because concessive relations presuppose and then deny an expected causal link (Konig and Siemund, 2000), they require additional inferencing to establish coherence. Although connectives trigger this inference, such an inference also needs to be made in implicit concessions to make sense of the discourse. The connective facilitates this process by signaling the type of inference that needs to be made. Supporting this interpretation, Experiment 1 showed a connective advantage in the spill-over region, where clause boundaries became clear. This is precisely the point at which readers must resolve uncertainty about the relation. The absence of such an effect earlier in the clause may reflect delayed inferencing or the chunked presentation of the materials. Overall, explicit result connectives may invite elaborative causal checking that slows processing, whereas concession connectives reduce the inferential burden associated with establishing a less predictable relation.

Our findings thus support a nuanced view: connectives do facilitate reading, but this effect is modulated by the type of discourse relation and the region that is examined. In particular, readers benefit more from connectives in non-causal (e.g., concessive) contexts, especially when the discourse relation is not readily inferable from context. Future research should further explore how connectives marking different types of relations interact with sentence structure and world-knowledge inferences to guide discourse comprehension.

5.2 Language-related differences in discourse processing

Experiment 2 shows that reading times are longer in German compared to English, even after controlling for differences in word length. Note, however, that the materials in Experiment 2 differed across languages, and so this pattern may reflect systematic structural differences that go beyond lexical length. For example, the English stimuli mostly end on (highly frequent) temporal adverbs (e.g., *ran a marathon last month*, *lost the contest this summer*), whereas the German equivalents cannot conclude with temporal adverbs due to grammatical constraints. Instead, the German stimuli often contain additional (new) information in the spill-over region (e.g., *brought a spider from Sicily*, *finished the marathon without problems*). This may increase surprisal and plausibly contribute to longer reading times in German. In Experiment 1, in which the items were the same across languages, revealed the opposite pattern: reading times of the spill-over

region were shorter in German than in English. However, in this experiment, syntactic structure differed across languages in the result condition.

Another factor that may contribute to the observed cross-linguistic differences concerns the role of world-knowledge-based causal schemas. Causal inferences are often guided by familiar event schemas (e.g., not having a valid train ticket means you cannot board the train) (Blochowiak et al., 2022; Kuperberg et al., 2011; Noordman et al., 2015; Wei and Knoeferle, 2023). The salience and frequency may differ across languages and cultures (e.g., in some countries you may be able to purchase a ticket on board of the train). Such differences could affect the ease with which readers establish coherence, independently of typological properties of the language. While the items in Experiment 1 were directly translated and thus comparable across languages, the stimuli in Experiment 2 differed in content [because this experiment was a direct replication of Blumenthal-Dramé (2021)], which may have introduced variability in schema salience. Taken together, these results highlight the complexity of cross-linguistic comparisons and underscore the importance of minimizing variation in stimulus design. Even subtle grammatical or pragmatic constraints can influence the structure and confound the processing load of seemingly parallel discourse segments. Note, however, that these cross-linguistic variations did not affect our main hypotheses.

Regarding the main question of cross-linguistic differences in sensitivity to connectives, neither Experiment 1 nor Experiment 2 provides strong evidence that German speakers benefit more from connectives than English speakers. The interaction between language and relation marking does not reach significance in either experiment. However, a significant three-way interaction emerges in Experiment 2: the interaction between marking and relation is larger in German than in English, contrary to our hypothesis (H3). This suggests that the effect of connectives may interact with language-specific features of coherence marking, though further replication is required to confirm this pattern and clarify the underlying mechanisms.

The typological hypothesis we tested follows Blumenthal-Dramé (2021) in assuming that speakers of more synthetic languages rely more on linguistic cues for establishing coherence, whereas speakers of analytic languages may depend more on contextual information. It is worth noting that both the current study and Blumenthal-Dramé (2021) focus on typologically similar languages from the same family. While German and English differ in degree of morphological synthesis, they are not situated at opposing ends of the analytic–synthetic continuum. For example, Chinese has even less inflection and is thus more analytic than English. It is possible that differences in discourse-level processing are more pronounced in languages that are more distinct. At the same time, the facilitative effect of the connective has been replicated across language families in many different languages, including French (Grisot and Blochowiak, 2017) and Chinese (Chen et al., 2019; Xu et al., 2018). This suggests that certain aspects of discourse comprehension may be universal rather than influenced by language-specific cues.

Moreover, the link between morphological typology and discourse processing is likely indirect. Morphological features such as case or gender marking are primarily relevant for

reference tracking and local cohesion, rather than for signaling discourse relations such as causality or concession. Indeed, Das (2014) shows that reference-based cues tend to co-occur with elaboration and comparison, not with causal or concessive relations. The absence of stronger cross-linguistic effects in the present study therefore suggests that typological differences along the analytic-synthetic dimension may influence reference-related coherence more than higher-level relational inference. Broader cross-linguistic comparisons, involving languages that are more distant on the analytic–synthetic continuum, are necessary to understand which aspects of discourse processing generalize and which are modulated by typological properties of the language.

5.3 Methodological considerations

Finally, we present two methodological considerations. First, the stimuli in the implicit condition all contain the word *and* (or *und*). While it constrains the interpretation of our findings to comparisons between more and less explicit marking (rather than between explicit and fully unmarked cases), it also avoids confounds from sentence-boundary effects and reflects the way result relations are often expressed in natural discourse (using the compound connective *and so*). Future studies could further test the generalizability of these effects using single-connective or truly implicit baselines, although the sentence-boundary effects would need to be accounted for in that case.

Second, a methodological difference between the experiments in the present study is that Experiment 1 used chunked self-paced reading. The reason for this is that there is often not a single word that disambiguates the relation. For comparability, we therefore summed the reading times in Experiment 2. Still, it is possible that power is decreased in chunked compared to word-by-word reading. A further disadvantage of chunked self-paced reading is that this method is less time-sensitive. The word-by-word self-paced reading task allowed for further analyses on the time course of the effect, revealing for instance that the effect of relation in Experiment 2 reaches significance in the spill-over and sentence-final region, but not in the critical region, whereas its interaction with language shows up in all regions but the final region. However, note that additional analyses also inflate the chances of a Type II error. It is therefore important that researchers have a priori hypotheses about where the effects show up, or conduct an analysis that takes this into account.

6 Conclusion

We presented two experiments investigating relation-dependent and language-dependent differences in the effect of the connective on reading. Across both studies, we tested three hypotheses: that connectives facilitate processing more for concession or contrast than result relations (H1), that the overall effect of connectives is stronger in German than in English (H2), and that the facilitative effect of connectives for concession or contrast (relative to result) is more pronounced in English than in German (H3).

Experiment 2 provided evidence in support of H1: the facilitating effect of connectives is larger in concession relations than in result relations. For result relations we find no evidence that connectives facilitate processing. This is consistent with the causality-by-default hypothesis (Sanders, 2005), which proposes that readers tend to assume causal coherence by default, thereby reducing the added value of an explicit connective. Experiment 1 revealed a similar difference in processing between contrast and result relations, but did not find a modulating effect of connective presence. We expect this to be due to connective salience and the context in which the relations were embedded.

With respect to cross-linguistic predictions, there was no support for H2 in either experiment: we find no evidence that the overall effect of connectives is stronger in German than in English. This goes against the prediction that speakers of synthetic languages may depend more on overt linguistic cues. A three-way interaction (relation × marking × language) did reach significance in Experiment 2, but its pattern went against H3: the relation-dependent effect of the connective was more pronounced in German, not English. Since this pattern does not replicate across experiments, it should be interpreted with caution. It remains possible that this effect was driven by materials, design, or other language-specific properties not controlled for in our study. Overall, our findings do not provide clear support for a typological account that predicts stronger reliance on connectives in synthetic languages. At the same time, we do not rule out the possibility that cross-linguistic variation affects discourse processing in more subtle or context-dependent ways. Since English and German are closely related and share many discourse conventions, differences might become more apparent in studies including a broader range of language families.

In sum, our results provide tentative evidence that the influence of connectives is shaped by discourse context but cannot be reliably predicted by relation type or language typology alone, at least in the case of the current study, with its focus on English and German. Importantly, Experiment 1 and Experiment 2 used different materials and different designs to test the same hypotheses. The fact that some effects, such as the interaction between connectives and relation type, emerged more clearly in Experiment 2 than in Experiment 1 emphasizes that connective effects are not uniform and may depend on subtle factors such as syntactic structure or the context of the relation. In other words, it highlights the sensitivity of connective effects to task design and linguistic context, as well as the need for more cross-linguistic work using carefully controlled designs to clarify when and how connectives influence discourse processing.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found below: https://tinyurl.com/crosslingconn.

Ethics statement

The studies involving humans were approved by Ethics Committee of Saarland University. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

MM: Conceptualization, Methodology, Visualization, Data curation, Investigation, Writing – review & editing, Writing – original draft, Formal analysis. FH: Writing – original draft, Writing – review & editing, Investigation, Data curation, Methodology, Formal analysis, Visualization, Conceptualization. SS: Methodology, Data curation, Writing – review & editing, Conceptualization. MSt: Conceptualization, Formal analysis, Writing – review & editing, Methodology, Funding acquisition, Supervision. VD: Formal analysis, Conceptualization, Writing – review & editing, Supervision, Methodology, Funding acquisition. MSc: Formal analysis, Conceptualization, Writing – review & editing, Supervision, Methodology, Funding acquisition.

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Supplementary material

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