From implicit to explicit

The processing of forward causal and temporal relations

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The presence of discourse relations can be marked explicitly with lexical items such as specialized and underspecified connectives or left implicit. It is now well established that the presence of specialized connective facilitates the processing of these relations. The question is to gauge how different degrees of explicitness affect the processing of discourse relations. This study investigates this question with respect to two relations, which are fundamental to our cognition and which are closely tied: causal relations and temporal relations. We carried out a self-paced reading experiment, in which we sought to compare the cost of inferring the presence of causal vs. temporal relations in the absence vs. presence of a connective indicating a given relation in French. For the explicit marking, two types of connectives were tested – one specialized for each relation (*donc* for causality and *puis* for temporality) and one underspecified (*et* in its temporal and causal readings). Overall, our results confirm the facilitator role of discourse connectives: we find that explicit discourse relations are processed faster than implicit ones. The specific (rather than underspecified) connective facilitates processing for temporal relations but not for causal relations; and temporal relations were read equally fast as causal relations.

Keywords: causal and temporal relations, French connectives, self-paced reading experiment, underspecification

1. Introduction

Temporal and causal relations are ubiquitous in our lives as well as in our discourses. Causal relations, in particular, have been extensively studied and are claimed to be fundamental to our cognition – a kind of cognitive default – as their proper recognition is vital to the accurate understanding of the world around us, starting from the early childhood (Spelke 1995). Usually, narrative stories with

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descriptions of events containing causal links are better recalled, are cited more often in summaries of texts, and are considered in general as more important than the portions of the text with no description of causally related events (Black & Bern 1981; Trabasso & van Den Broek 1985). Temporal relations have been studied much less in the psycholinguistic literature, although interest in their cognitive status has newly increased. For instance, temporal relations have been recently included in the set of cognitive coherence relations (Evers-Vermeul Hoek & Scholman 2017; Hoek, Evers-Vermeul & Sanders 2019) on a par with other discourse relations, such as causal or additive relations.[1]

The presence of discourse relations can be marked explicitly with lexical items such as specialized and underspecified connectives or left implicit. It is now well established that the presence of specialized connective facilitates the processing of these relations. Prior experimental research on the role of specialized connectives in processing discourse relations, such as causal relations (Millis & Just 1994; Cozijn et al. 2011) and contrastive relations (from Haberland 1982 onwards), have demonstrated that the presence of a specialized connective speeds up processing. In particular, this effect has been found at the initial part of the clause. Numerous other studies have confirmed that the facilitating effect of specialized connectives' effect occurs on the immediately following segment. Thus, it facilitates the integration of the clause as it unfolds, because readers build the coherence relation incrementally (Sanders & Noordman 2000; Mak & Sanders 2013; Canestrelli et al. 2013; Zufferey 2014; van Silfhout et al. 2015). Fewer studies have investigated the role of temporal connectives for processing coherence relations (Segal et al. 1991; van Silfhout 2015; Grisot & Blochowiak 2019).

An issue that arises is whether this facilitating effect may be also found for connectives marking discourse relations in a less explicit way, such as underspecified connectives. In the present research, we endeavour to investigate this issue. Thus, our research question is: how do different degrees of explicitness affect the processing of forward temporal and causal discourse relations? To answer this question we carried out a self-paced reading experiment, in which we manipulated the degree of explicitness: implicit; explicit, using an underspecified connective; and explicit, using a specialized connective. For the underspecified marking, we use the connective *et* ('and'), which can relate many types of relation including temporal and causal relations. For the specialized marking, we use the connectives *puis* ('then')

1. It is worth mentioning that, in other frameworks, temporal relations have always been included among coherence relations: see Rhetorical Structure Theory (Mann & Thompson 1987; Taboada & Mann 2006), Segmented Discourse Representation Theory (Lascarides & Asher 1993; Asher & Lascarides 2003), Penn Disourse TreeBank (Prasad, Dinesh, Lee, Miltsakaki, Robaldo, Joshi & Webber 2008), and the Event-indexing model (Zwaan, Langston & Graesser 1995).

for temporality and *donc* ('so') for causality. Two main views can be found in the literature concerning the processing of discourse relations with and without connectives are: (i) the **Facilitator Connective hypothesis** and the **Specific Connective hypothesis**, according to which connective use facilitates access to the underlying relation, with more specific connectives making the relation more accessible; and (ii) the **Causality-by-default hypothesis**, according to which causal links are most salient to our cognition, and thus easier to process.

Below, we first describe in more detail the two hypotheses regarding the role of connectives (Section 2.1), and then discuss the hypothesis regarding causality (Section 2.2). Based on the literature presented in Section 2, we formulate predictions following from these hypotheses for our online experiment (Section 3). Finally, we discuss the results we obtained in Section 4.

2. Literature review

2.1 Means of expressing a relation: From implicit to degrees of explicitness

In French, as in many other languages, comprehenders have to recover relations linking situations described by a text in order to understand the text fully. These relations can be marked more or less explicitly with a linguistic marker, such as a connective, or left implicit (Spooren 1997; Roze et al. 2012; Crible & Demberg 2020) as in (1)–(3). For instance, the comprehender needs to grasp the presence of a temporal relation in (1), a causal relation in (2), and a simple additive or list relation in (3).

(1) Tom a enlevé ses chaussures. Il est allé au lit.
'Tom took off his shoes. He went to bed.'

(2) Tom était fatigué. Il est allé au lit.
'Tom was tired. He went to bed.'

(3) Les loups vivent dans la forêt. Ils chassent en meute.
'Wolves live in forests. They hunt in packs.'

While these relations are not explicitly signalled, they are fully retrievable according to comprehenders' world knowledge. This means that their **implicit** presence is sufficient for the text to be understood by the reader. It should be noted that the status of temporal and causal relations is not equal with respect to the implicit way of signalling them: while it is possible to reverse the order of segments in the case of causal relations with no changes to the meaning (see Bar-Lev & Palacas 1980) (compare (2) with (5)), this operation is not possible for temporal relations, as shown in (4). With additive relations, the linear time course is usually irrelevant.

(4) Tom a enlevé ses chaussures. Il est allé au lit. ≠ Tom est allé au lit. Il a enlevé ses chaussures.
'Tom took off his shoes. He went to bed. ≠ Tom went to bed. He took off his shoes.'

(5) Tom était fatigué. Il est allé au lit = Tom est allé au lit. Il était fatigué.
'Tom was tired. He went to bed. = Tom went to bed. He was tired.

These relations can also be signalled by means of linguistic markers with different **degrees of explicitness**. There are **specific linguistic connectives** dedicated to temporal and causal relations in both the iconic (forward progression of time) and non-iconic (backward progression of time) orders. For instance, the adverbial *puis* 'then' can be used to mark a forward temporal relation (6),[2] and *donc* 'so' a forward causal relation (7), whereas *après* 'after' can be employed to indicate a backward temporal relation (8), and *parce que* 'because' a backward causal relation (9).

(6) Tom a enlevé ses chaussures, *puis* il est allé au lit.
'Tom took off his shoes, then he went to bed.'

(7) Tom était fatigué, *donc* il est allé au lit
'Tom was tired, so he went to bed.'

(8) Tom est allé au lit *après* avoir enlevé ses chaussures.
'Tom went to bed after he took off his shoes.'

(9) Tom est allé au lit *parce qu*'il était fatigué.
'Tom went to bed because he was tired.'

These linguistic markers signal **explicitly** what type of relation the comprehender needs to look for while reading a text. As such, they function as procedural instructions guiding the inferential process during the course of discourse comprehension (Blakemore 1987). Many studies, dedicated mostly to causality, have sought to test whether the presence of such linguistic markers speeds up access to the type of relation they convey. It has been demonstrated that explicit marking of a causal

2. As pointed out by an anonymous reviewer, English *then* is less specialized for forward temporal relations than the French *puis*. For example, in the English sentence *Tom took off his shoes, then he went to bed*, the relation may be ambiguous between temporal and purposive, the latter being a specific type of forward causal relation (Andersson & Spenader 2014). Nevertheless, a purposive interpretation is less plausible for the French sentence *Tom a enlevé ses chaussures, puis il est allé au lit*, given the fact that the adverbial *puis* is, semantically speaking, a temporal connective that marks the temporal succession of events, being thus specialized for forward temporal relations (Bras et al. 2001; Gosselin 2007; de Saussure 2007; Grisot & Blochowiak 2019).

relation does facilitate the integration of the information in the segment following the connective more so than cases when the relation is left implicit (Britton, Glynn, Meyer & Penland 1982; Haberlandt 1982). However, in other types of tasks – such as free recall – this facilitating effect is not always witnessed (Britton et al. 1982; Meyer 1975; cf. Degand, Lefèvre & Bestgen 1999 regarding possible discrepancies between online and offline results). Furthermore, the type of text studied appears to play a role: for some scholars, expository texts are preferred over simple narratives in order to avoid an oversimplification of the experimental material and expose participants to new information (Sanders & Noordman 2000).

Another option for marking a given relation is to use a connective which is **underspecified** with respect to the relation, an option that is usually overlooked in experimental research (see, however, Cain & Nash 2011 for a developmental study). A typical case is the conjunction *et* 'and', which is compatible with a plethora of relations (see, for instance, Blakemore 1987; Carston 1993, 1998, 2002; Luscher & Moeschler 1990; Levinson 2000; de Saussure & Sthioul 2002; Blochowiak 2016 for a pragmatic analysis; Spooren 1997; Pander Maat 1999; Kitis 2000; Gómez Txurruka 2003; Duran, McCarthy, Graesser & McNamara 2007; Crible 2017 for a discourse analysis from a psycholinguistics perspective); it also plays multiple roles at the discursive level, confirming its high polyvalence in numerous languages (Crible et al. 2019). Interestingly, *and* is very well suited to both temporal and causal relations with forward movement of time, as shown in (10) and (11) respectively.

(10) Tom a enlevé ses chaussures *et* il est allé au lit.
'Tom took off his shoes *and* he went to bed.'

(11) Tom était fatigue et il est allé au lit.
'Tom was tired *and* he went to bed.'

It is widely accepted that the core semantic meaning of the French connective *et* and English *and* is minimal: it encodes a concept of logical conjunction (Blakemore 1987; Wilson & Sperber 1998; Blakemore & Carston 1999), which can have cumulative or distributive readings (de Saussure & Sthioul 2002) or simply expresses additivity (Spooren 1997; Zeevat & Jasinskaja 2007). In any case, the meaning of French *et* and English *and* is underspecified,[3] and can become more specific in the context depending on the type of eventualities described.

The precise sort of pragmatic mechanisms that *and* puts into play have been extensively examined in various pragmatic frameworks. For instance, temporal

3. For example, English *and* can also be used to express purposive relations (Croft 2010). Nonetheless, empirical studies on French *et* report this phenomenon as very marginal (Crible et al. 2019). As such, French sentences coordinated with *et* are not ambiguous between forward temporal and forward causal/purpose interpretations.

and causal interpretations of *and* are quite unanimously viewed as a pragmatic type of inference: implicatures for Grice (1975), I-implicatures for Levinson (2000) or explicatures for relevance theorists (Sperber & Wilson 1986; Carston 2002). The difference concerns the order of derivation of temporal and causal relations: for Levinson (2000), the conjunction *and* has a default temporal interpretation, especially when sentences describe the forward temporal order of events in the past tense; for Carston (1993, 1998, 2002), on the other hand, there is no intrinsic primacy of temporal relations over causal relations, nor vice versa, since the derivation depends on the availability of mental schemas behind each relation guiding the interpretation process. Such mental schemas or cognitive scripts pertain to the encyclopaedic knowledge that interlocutors share about types of situations described, and which are necessary to derive the full propositional form of an utterance which can be then evaluated as true or false. For instance, the accurate derivation of the truth-conditions for a causal reading (as in (12)) or a temporal (as in (13)) reading is guaranteed by the synergy of the principle of relevance and the contextual assumptions stored in the form of mental schemas and shared by the participants of the conversation.

(12) Mary dropped her mug on the tiles and it broke.

(13) Mary took off her slippers and put on her shoes.

In (12), comprehenders can infer the causal relation between the two events described by way of their background knowledge about a causal rule activating a mental schema according to which dropping a mug on tiles will cause it to be broken (see also Cozijn et al. 2011; Blochowiak 2014). Similarly in (13), the full propositional form evaluable as true or false can be achieved only if, in addition to the occurrence of the two events described, the comprehender establishes that they follow some common sequence of events, which is presumably also stored in comprehenders' background knowledge in a form of mental schema reflecting some temporal rule. From the processing perspective, it is important to note that the degree of availability of these mental schemas is responsible for the rapidity with which a given relation is accessed: more salient relations can be retrieved by the comprehender with greater speed than less salient relations, independently of the type of relation (temporal or causal). In the same vein, Recio Fernández (2020) argued that it is mind-stored assumptions that play a key role in the comprehension process of causal and argumentative discourse relations, rather than the concept of causality by itself.

A few experimental studies that directly compared temporal and causal relations have yielded conflicting results. Thompson et al. (2012) tested English *and* using a RSVP technique (Rapid Serial Visual Presentation), and found that causal interpretations give rise to faster reading times than temporal interpretations. However, several problems have been noted in their design, as reported in Blochowiak

& Castelain (2018) who conducted a self-paced reading experiment with French *et*. They observed that the causal interpretations of *et* were read at a slower pace than temporal interpretations. Consensus is yet to emerge on the processing of temporal and causal relations with the conjunctions *et* and *and*. Moreover, no study has investigated possible differences between underspecified *et*/*and* and its specialized counterparts *puis*/*then* or *donc*/*so*. This paper intends to fill that gap.

In sum, two hypotheses have been formulated have been formulated in the literature. The first is the **Facilitator Connective hypothesis**, according to which the presence of a linguistic marker signalling a given relation would facilitate the integration of this relation, resulting in shorter processing times in the region following the linguistic marker (Sanders & Noordman 2000; Canestrelli et al. 2013). The second is the **Specific Connective hypothesis**, according to which the more specific the linguistic marker is, the greater the facilitating effect found on the segment following it (Sanders 2005).

2.2 Paradox of causality: Structurally complex but cognitively simple?

In the psychological literature, causal relations are most often compared to additive relations, and the main claim – called the **Causal Complexity hypothesis** – is that causal relations are more complex than additive relations as causality is informationally richer (Sanders 2005). For instance, to say that two events happened, as in (14), is less informative than to say that two events happened and there was a causal link between them, as in (15).[4]

(14) Tom was tired and he also went to bed.

(15) Tom was tired and so he went to bed.

The Causal Complexity hypothesis has been verified in developmental studies, where it was demonstrated that children first acquire simple additive relations, then more complex temporal relations, followed by causal relations, and finally the most complex adversative relations (Piaget 1924/1961; Bloom, Lahey, Hood, Lifter & Fiess 1980; Clark 2003; Evers-Vermeul & Sanders 2009). Yet this pattern has not been confirmed by processing studies with adult speakers (Haberlandt & Bingham 1978; Sanders & Noordman 2000).

These conflicting results gave rise to what is called the **Paradox of Causal Complexity**, which points to the fact that – even if causality can arguably be considered

4. It should be also noted that causality subsumes both additivity (the fact that two events were causally related necessary means that the two events occurred) and temporality (two eventualities linked causally happened in certain temporal order – usually a forward temporal order, although temporal overlapping is also possible; see de Saussure 2003; Blochowiak 2009).

a more complex relation than noncausal relations, such as additive relations – processing research shows that causal relations actually demand less cognitive effort than additive relations (Sanders 2005). Given this paradox, a new proposal has been formulated – the **Causality-by-default hypothesis** (Sanders 2005) – which states that readers by default search for the richest information, and thus assume from the start that there is a causal relation between the events described in the sentences they read. Only once they realize that the causal relation cannot fit will they go for a simpler relation (Sperber, Premack & Premack 1996). The prediction that follows from this hypothesis is that causal relations – coming first to readers' minds – are processed faster than other types of relations, be they less complex, such as additive relations.

Studies seeking to verify this hypothesis compared causal and noncausal relations, such as additive relations. For instance, Sanders & Noordman (2000) carried out experiments on expository texts, which they used to test specific types of causal and additive relations: namely **problem-solution** and **list** respectively, as illustrated by their own examples below (Sanders & Noordman 2000: 43).

(16) The spoonbill is now threatened in its continued existence in the Netherlands. The Society for the Protection of Birds has taken protective measures.

(17) A robin is a singing bird. Robins live in woods. They usually have 3 to 4 eggs.

These types of relations have been chosen for their clear characteristics in their discursive structures. It has been observed that the difference between problem-solution and list relations is that the problem-solution relations are highly organizing structures of discourse, whereas relations between list elements present a much weaker type of discourse connection (Horowitz 1987; Meyer & Freedle 1984). Sanders & Noordman (2000) tested these two types of relations in two setups: when they were left implicit (as in (16) and (17)); and when they were explicitly marked with the linguistic markers, the latter being expressed as a full sentence which preceded the target sentence (hence not as a connective). They found that causal relations in the problem-solution setup were processed faster. In addition, the linguistic marking facilitated the processing and verification of a given relation but did not have an effect on recall of these relations. In summary, this study provided evidence that, in expository texts, causal relations of the problem-solution type are indeed easier to process than otherwise much simpler additive relations of the list type, and that the linguistic marking facilitates the processing of these relations.

However, given the high divergence in the discourse-organizing potential of the two relations mentioned above, a fairer comparison is needed, namely between types of relations that would be more similar in terms of their potential

to connect the discourse segments. For this reason, in our study we have chosen to test short narratives involving simple, everyday causal sequences of events that will be compared to equally simple everyday temporal sequences of events. The crucial point is that both types of relations appeal to schematic sequences of events invoking some commonly shared mental schemas, be they causal or temporal. As for the order of mention in the discourse, the forward sequences have been chosen because – as previous studies have demonstrated – this configuration seems to be easier to process in both causal and temporal relations. To keep the two sets of relations maximally similar, we have also controlled for the aspectual dimension of the events described in the experimental materials. From the different aspectual classes (cf. Vendler 1957) – events (achievements and accomplishments), activities and states – we chose only events, because of their characteristics as bounded type of eventualities. Below, we provide an example of temporal relations in (18) and one of causal relations in (19).

(18) Sarah a mis ses baskets, ***puis*/ *et*** / Ø elle est sortie faire du jogging avec l'espoir de perdre un peu de poids.
'Sarah put on her sneakers, ***then*/ *and*** / Ø she went out for a run hoping to lose some weight.'

(19) Sébastien a gagné un concours de piano ***donc/ et*** / Ø le professeur l'a félicité chaleureusement, fier d'avoir un tel élève dans son école.
'Sébastien won a piano competition, ***so*** / ***and*** / Ø the teacher warmly congratulated him, proud to have such a student in his school.'

3. The present study

The experimental work discussed in this section consists of a **self-paced reading experiment** carried out in French. In this experiment, participants read sentences expressing forward causal or temporal relations, either expressed implicitly or overtly marked with either a specialized connective (*puis* and *donc*) or the conjunction *et*. We used a 2×3 within-group design, with two variables: **Relation** (temporal and causal); and levels of **Explicitness** (the underspecified connective, temporal *et* and causal *et*; the specialized connective, *puis* and *donc*; and the implicit cases, both temporal implicit and causal implicit).

3.1 Hypotheses and predictions

The studies presented in the previous sections give rise to a series of hypotheses, and their subsequent predictions for online experimental testing. Table 1 shows the three variables under consideration: Relation and two Degrees of explicitness.

Table 1. Summary of hypotheses and predictions in terms of mean reading times

Hypothesis	Variable	Predictions
Facilitator Connective hypothesis	Degrees of explicitness	explicit (any connective) is processed faster than implicit
Specific Connective hypothesis	Degrees of explicitness	specific connective is processed faster than underspecified connective
Causality-by-default hypothesis	Relation	causal is processed faster than temporal implicit causality is processed faster than implicit temporality causal *et* is processed faster than temporal *et*

The first and second sets of hypotheses and predictions concern the means of expressing a given relation. The Facilitator Connective hypothesis states that, in general, any explicit linguistic means of signalling the presence of a given relation should speed up its integration. The Specific Connective hypothesis provides a finer-grained prediction, according to which the more specific the connective is for a given relation, the greater the facilitating effect will be.

The third set of hypotheses and predictions regards the type of relation. The prediction is that causality comes by default, and causal relations should thus be processed faster than temporal relations. The prediction is that causality will be accessed faster than temporality when the relation is left implicit, as well as when it is marked by the underspecified connective *et*.

3.2 Self-paced reading experiment

3.2.1 *Participants*

Participants in this experiment were 47 second- and third-year students from the University of Neuchâtel (32 females, mean age: 21.42, range 19–25). All participants were native speakers of French studying language sciences or speech therapy. Their participation in the experiment was part of their activity for one class in linguistics, and was unpaid.

3.2.2 *Materials and procedure*

We used a 2×3 within-group design, with two variables: **Relation** and levels of **Explicitness**, as shown in Table 2.

Table 2. The 2×3 experimental design

		Relation: temporal vs. causal	
Degrees of explicitness implicit vs. underspecified connective vs. specialized connective	explicit	temporal with *puis*	causal with *donc*
		temporal with *et*	causal with *et*
	implicit	implicit temporal	implicit causal

The six experimental conditions are presented in Table 2, and illustrated in Examples (20)–(25). Each experimental item consisted of pairs of sentences representing short narratives, also called *textoids* (cf. Graesser et al. 1997; Kaiser 2019). In each item, the second sentence was subdivided into three regions: the subject-verb, the complement and the adjunct (which was the wrap-up reading region). Comparing Examples (21) and (22) to (20), as well as (24) and (25) to (23), the distinction between causal and temporal relations in the implicit and underspecified cases can only be made when the two sentences' content is taken into account.[5]

(20) Sarah a mis ses baskets, ***puis*** elle est sortie faire du jogging avec l'espoir de perdre un peu de poids.
'Sarah put on her sneakers, then she went out for a run hoping to lose some weight.'

(21) Sarah a mis ses baskets, ***et*** elle est sortie faire du jogging avec l'espoir de perdre un peu de poids.
'Sarah put on her sneakers, and she went out for a run hoping to lose some weight.'

(22) Sarah a mis ses baskets, Ø elle est sortie faire du jogging avec l'espoir de perdre un peu de poids.
'Sarah put on her sneakers, Ø she went out for a run hoping to lose some weight.'

(23) Philippe a oublié de mettre de l'essence, ***donc*** sa voiture s'est arrêtée au beau milieu de la route.
'Philip forgot to refuel, so his car stopped right in the middle of the street.'

5. As pointed out by an anonymous reviewer, in the underspecified or the implicit condition, it can be argued that a *conclusion* in Sweetser's (1990) terms (see also Hansen 2012) or a *pragmatic* relation (Sanders, Spooren & Noordman 1992) is conveyed.

(24) Philippe a oublié de mettre de l'essence, ***et*** sa voiture s'est arrêtée au beau milieu de la route.
'Philip forgot to refuel, and his car stopped right in the middle of the street.'

(25) Philippe a oublié de mettre de l'essence, Ø sa voiture s'est arrêtée au beau milieu de la route.
'Philip forgot to refuel, Ø his car stopped right in the middle of the street.'

To ensure that the items in the underspecified and the implicit conditions had the intended temporal vs. causal interpretation, we used the linguistic test with the connective *because*. As such, reversing the order of the two segments and overtly marking the discourse relation expressed with *because* must be felicitous for causal items but not for temporal ones. In the case of temporal items, this test ensures that no other relation (such as causal or purposive) is present in addition to the temporal relation. Applying the *because* test to Examples (24) and (25) results in the rephrasing provided in (26), whose felicitousness confirms that a causal relation is expressed in these items. In contrast, (27) (which is the rephrasing using the *because* test of a temporal item) does not felicitously express an objective causal relation. This demonstrates that this item does indeed express a temporal relation.[6]

(26) La voiture de Philippe s'est arrêtée au beau milieu de la route parce qu'il a oublié de mettre de l'essence.
'Philip's car stopped right in the middle of the street because he forgot to refuel.'

(27) ?? Sarah est sortie faire du jogging parce qu'elle a mis ses baskets.
'Sarah went out for a run because she put on her sneakers.'

As shown in Examples (28) and (29), we measured reading times on two regions of interest situated at the beginning of the second sentence: the region of the **subject-verb** of the second sentence (number 4 immediately following the connective in the explicit condition, and number 3 in the implicit condition); and the region of the **complement** of the second sentence (number 5 in the explicit condition, and number 4 in the implicit condition) (cf. also Cain & Nash 2011). To have the same number of reading regions in all experimental conditions – i.e. 6 – the wrap-up segment in the implicit condition (rather than the explicit conditions) was divided

6. However, it should be stressed that an overt marking of a predicate expressing the agent's will makes the example felicitous: *Sarah put on her sneakers because she **wanted** to go out for a run*. This shows that the purposive relation preferentially requires the presence of a modal verb, such as *want* (as suggested by Andersson & Spenader 2014, who found that, in 60–65% of cases, purpose relations are expressed with a connective and a modal verb cue).

into two, as shown in (29). Consequently, we did not measure the reading times on the wrap-up region.

(28) **Explicit**: [Sarah a mis[1]] [ses baskets[2]], CONNECTIVE[3] [elle est sortie[4]] [faire du jogging[5]] [avec l'espoir de perdre un peu de poids.[6]]
[Sarah put on[1]] [her sneakers[2]], CONNECTIVE[3] [she went out[4]] [for a run[5]] [hoping to lose some weight.[6]]

(29) **Implicit**: [Sarah a mis[1]] [ses baskets[2]], Ø [elle est sortie[3]] [faire du jogging[4]] [avec l'espoir de perdre[5]] [un peu de poids.[6]]
[Sarah put on[1]] [her sneakers[2]], Ø [she went out[3]] [for a run[4]] [hoping to lose[5]] [some weight.[6]]

The 42 experimental items (21 temporal and 21 causal) had a variant in each experimental condition, resulting in 126 variants of the experimental items. 18 fillers, having the same structure (9 with the connective *mais* and 9 without any connective) were also used in the experiment. The total of 126 versions of the experimental items were distributed in 3 lists. Each participant saw only one list consisting of 60 sentences (42 items and 18 fillers), and read experimental items from all the 6 conditions. The order of presentation was randomized. A total of 10 yes/no comprehension questions appeared randomly within each list to assess the participants' level of attention. Participants could answer by pressing a key for *yes* or for *no*, according to their choice. For example, the experimental item from (20)–(21) would be followed by a comprehension question as in (30), and would require a *no* answer:

(30) Sarah a-t-elle mis ses bottes de pluie ?
'Has Sarah put on her rubber boots?'

On pressing the space bar, the different regions appeared consecutively on the screen, and disappeared from the screen as the readers went on to the next region. This design allowed the participants to read each region individually, and prevented them from pressing the space bar in order to see all the regions before starting to read. Experiments were designed with the E-prime software (Schneider et al. 2012), and participants were tested individually. Each session began with written instructions displayed on the screen, followed by a training phase, in which the participants saw 6 sentences similar to the items and 4 sentences similar to the fillers. At the end of the training phase, the participants were given the opportunity to ask questions of the experimental coordinator before the actual experiment started. Each series of readings began with a fixation cross in the middle of the screen for 1000 ms. There was no time constraint imposed for the task, and each participant completed the experiment within approximately 15 minutes.

3.2.3 *Analysis*

All answers to the comprehension question were checked. One participant had a success rate of lower than 70%, and this participant was removed from the data set. For the remaining 46 participants, the average level of success in the comprehension questions was 85%. Before conducting the analysis, the data were cleaned in two phases. In the first phase, extreme values were removed by deleting observations under 50 ms and over 4000 ms (milliseconds) measured for the first critical region – the subject-verb region of the second sentence (segment 4 in the explicit condition, and segment 3 in the implicit condition) – as these reading times are not considered in the literature to represent normal reading times for short segments such as those used in our experiment (cf. Zufferey 2014). Thus, 3 observations (0.001% of the data) were excluded. Following one of the procedures spelled out by Field, Miles & Field (2014), outliers were removed from the data for all observations above and below 2.5 SD from the subject's mean values for each of the two target regions (see also Zufferey & Gygax 2016; Crible & Pickering 2020). This corresponded to 75 observations (0.03% of the data) for the subject-verb region and 86 observations for the region of the complement (0.04%). The mean reading times (standard errors between parentheses) for the two target regions (as illustrated above in Examples (20)–(25)) in each of the six experimental conditions are reported in Table 3.

Table 3. Mean reading times and standard deviations (ms) for the target regions

	Region of the second sentence	
Condition	**Subject-verb**	**Complement**
Causal.implicit	845.65 (339.99)	811.05 (376.61)
Causal.*donc*	783.05 (310.00)	753.09 (295.66)
Causal.*et*	795.17 (358.51)	783.22 (336.14)
Temporal.implicit	788.13 (346.71)	826.94 (327.46)
Temporal.*puis*	769.12 (340.87)	796.3 (327.71)
Temporal.*et*	750.13 (311.69)	815.18 (335.24)

Data were analysed by fitting linear mixed-effects models using the R software (R Development Core Team 2010, version 3.1.2). This allows us to include both participants and items as random factors in all analyses, therefore avoiding the "language-as-fixed-effect-fallacy" by separating F1 and F2 analyses (Brysbaert 2007; Clark 1973). Models were tested using the lmer() function of the lmer4 package of R, and model comparisons were assessed using the anova() function, which calculates the chi-square value of the log-likelihood to evaluate the difference between models, following Baayen's (2008) procedure.

We carried out two types of analysis. In the first analysis, we were interested in the coarse-grained effect of the level of explicitness (explicit vs. implicit) and of the relation expressed (causal vs. temporal), and we analysed the whole set of data. In the second analysis, we were interested in finer-grained findings, such as the effect of the level of explicitness (implicit vs. underspecified connective vs. specialized connective) within each type of relation (causal vs. temporal), as well as the effect of the relation expressed (causal vs. temporal) when the level of explicitness (implicit and underspecified connective) does not inform the comprehender about which relation is expressed. The second type of analysis was therefore carried out on subsets of data: causal, temporal, implicit and underspecified connective.

Following Field et al. (2014), we built the models by going from the simplest model to the model of interest. As such, in the first analysis and for each of the two target regions, we first tested a model that only encompassed items and participants as random factors (i.e., random intercepts). We then compared this model to one including levels of Explicitness as a fixed factor, and finally one that incorporated both levels of Explicitness and Relation as fixed factors. In the second type of analysis, we compared the simplest model to the one in which we incorporated the variable levels of Explicitness (implicit vs. underspecified connective vs. specialized connective) for the subsets of causal and temporal relations, and the variable Relation in the subsets of implicit and underspecified connective.

3.2.4 *Results*

First analysis. In the **subject-verb region** of the second sentence, adding Degrees of explicitness to the simplest model – which only included items and participants as random effects – significantly improved the model ($\Delta\chi^2 = 14.35$, $\Delta df = 1$, $p < .001$). However, adding Relation did not further improve the model's fit ($\Delta\chi^2 = 1.40$, $\Delta df = 1$, $p > .05$, *ns.*), as the processing time of the subject-verb region did not vary with respect to the relation expressed: temporal relations are processed as fast ($M = 769.03$, $SD = 333.39$) as causal relations ($M = 807.86$, $SD = 227.52$) ($\beta = -38.81$, $SE = 32.93$, $p > .05$). The model including Degrees of explicitness as a fixed factor, and items and participants as random factors, showed that when the region subject-verb was preceded by a connective, participants read it faster ($M = 774$, $SD = 330.96$) than when the relation expressed was left implicit ($M = 816.98$, $SD = 344.29$) ($\beta = -45.98$, $SE = 12.911$, $p < .001$).

In the **complement region** of the second sentence, we found exactly the same results as in the previous region. Adding Degrees of explicitness to the simplest model – which only included items and participants as random effects – significantly improved the model ($\Delta\chi^2 = 13.69$, $\Delta df = 1$, $p < .001$). Adding Relation did not further improve the model's fit ($\Delta\chi^2 = 0.99$, $\Delta df = 1$, $p > .05$, *ns.*), as temporal relations were processed as fast ($M = 812.74.03$, $SD = 330.07$) as causal relations ($M = 782.39$, $SD = 338.15$) ($\beta = 30.72$, $SE = 31.02$, $p > .05$, *ns.*). The model including

Degrees of explicitness as a fixed factor and items and participants as random factors showed that participants read the region complement of the second sentence faster when the relation expressed was explicitly marked with a connective ($M = 786.97$, $SD = 324.54$) than when it was left implicit ($M = 818.97$, $SD = 352.78$) ($\beta = -43.74$, $SE = 11.80$, $p < .001$).

Second analysis. Figures 1 and 2 illustrate the results on the subject-verb region (Figure 1) and the complement region (Figure 2) for all the experimental conditions.

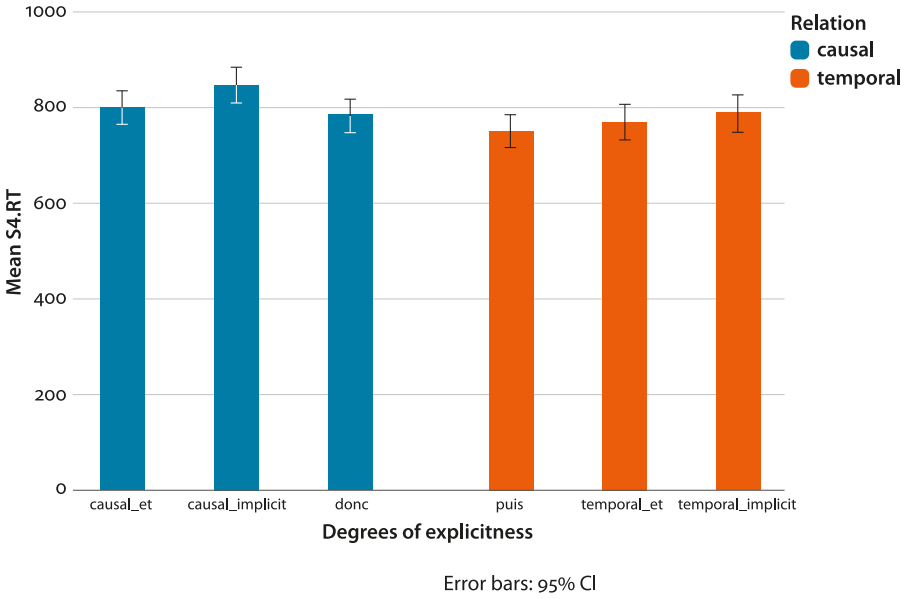

Figure 1. Mean RTs (ms) on the subject-verb region

Causal subset

In the **subject-verb region**, adding Degrees of explicitness (implicit vs. *donc* vs. causal *et*) to the simplest model – which only included items and participants as random effects – significantly improved the model ($\Delta\chi^2 = 14.23$, $\Delta df = 2$, $p < .001$). This second model showed participants were faster to read the subject-verb region when it was introduced by the specialized connective *donc* ($M = 783.05$, $SD = 310.00$) ($\beta = -66.51$, $SE = 18.75$, $p < .001$) or the underspecified connective *et* ($M = 795.17$, $SD = 358.51$) ($\beta = -54.67$, $SE = 18.73$, $p < .001$) than when no connective was present ($M = 845.65$, $SD = 339.99$), as shown in Figure 1. The same model showed that when the subject-verb region is preceded by the specialized connective *donc*, participants read it as fast as they did when it is preceded by the underspecified connective *et* ($\beta = -11.84$, $SE = 18.70$, $p > .05$, *ns.*).

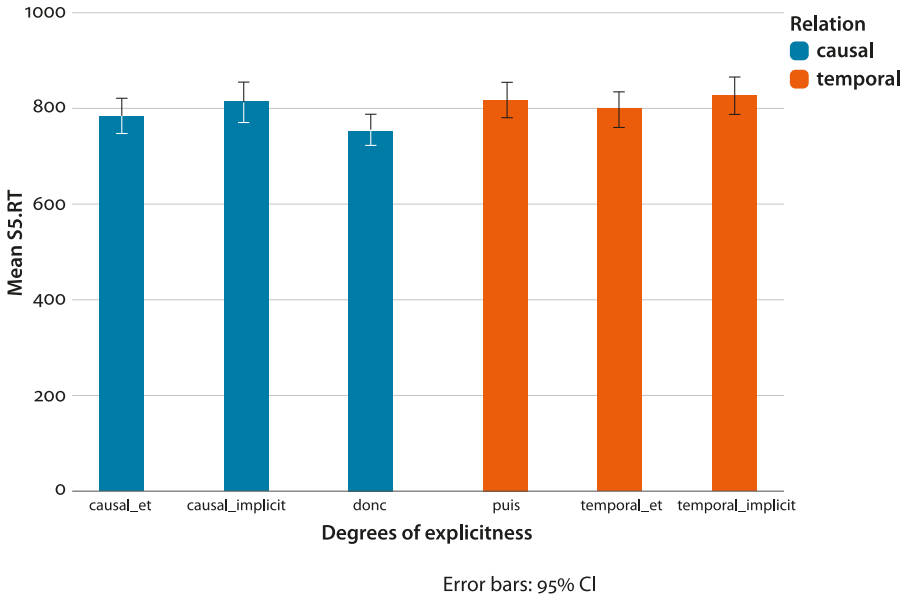

Figure 2. Mean RTs (ms) on the complement region

In the **complement region**, we found very similar results. The model with Degrees of explicitness as a fixed factor and items and participants as random factors showed that the facilitating effect of the connective persists in the complement region: participants read this region faster when the second sentence was introduced by the specialized connective *donc* ($M = 753.09$, $SD = 295.00$) ($\beta = -62.65$, $SE = 19.05$, $p < .005$) or by the underspecified connective *et* ($M = 783.22$, $SD = 336.14$) ($\beta = -37.32$, $SE = 19.03$, $p < .005$) than when no connective was present ($M = 811.05$, $SD = 376.61$), as shown in Figure 2. As in the previous region, the same model showed that when the second sentence is preceded by the specialized connective *donc*, participants read the complement region as fast as when they did it is preceded by the underspecified connective *et* ($\beta = -25.32$, $SE = 19.00$, $p > .05$, *ns.*).

Temporal subset

In the **subject-verb region**, adding Degrees of explicitness (implicit vs. *puis* vs. temporal *et*) to the simplest model – which only included items and participants as random effects – did not significantly improve the model ($\Delta\chi^2 = 3.14$, $\Delta df = 2$, $p > .05$, *ns.*), as participants were as fast to read this region when it was preceded by the underspecified connective *et* ($M = 769.12$, $SD = 340.87$) as they were when the relation expressed was left implicit ($M = 788.13$, $SD = 346.71$) ($\beta = -19.59$, $SE = 21.00$, $p > .05$, *ns.*), as shown in as shown in Figure 1. For the specialized connective *puis*, however, we found that participants read this region faster when it was preceded by *puis* ($M = 750.13$, $SD = 311.69$) than when the relation expressed was left implicit

($\beta = -19.59$, $SE = 21.00$, $p = .07$ two-tailed test, .035 one-tailed test). The same model showed that when the subject-verb is preceded by the specialized connective *puis*, participants read it as fast as they did when it is preceded by the underspecified connective *et* ($\beta = -17.02$, $SE = 20.43$, $p > .05$, *ns.*).

In the **complement region**, adding the Degrees of explicitness to the simplest model – which only included items and participants as random effects – marginally improved the model ($\Delta\chi^2 = 5.05$, $\Delta df = 2$, $p = .07$). This model showed that participants were faster to read the region complement of the second sentence when the relation expressed was explicitly marked with the underspecified connective *et* ($M = 796.30$, $SD = 340.87$) than when it was left implicit ($M = 826.94$, $SD = 327.46$) ($\beta = -44.14$, $SE = 19.62$, $p < .005$), as as shown in Figure 2. The same model showed that when the second sentence is preceded by the specialized connective *puis*, participants read the complement region as fast as they did when it was preceded by the underspecified connective *et* ($\beta = 23.05$, $SE = 19.02$, $p > .05$, *ns.*), as well as when the relation expressed was left implicit ($\beta = -21.09$, $SE = 19.25$, $p > .05$, *ns.*).

Underspecified connective subset

In the **subject-verb region**, adding Relation to the simplest model did not improve the model ($\Delta\chi^2 = 0.37$, $\Delta df = 1$, $p > .05$, *ns.*), as participants were as fast to read the subject-verb region when it was preceded by the underspecified connective *et* as they were when the relation expressed was temporal ($M = 769.12$, $SD = 340.878$) or causal ($M = 795.17$, $SD = 358.14$) ($\beta = -25.20$, $SE = 41.53$, $p > .05$, *ns.*), as shown in Figure 3.

In the **complement region**, adding Relation to the simplest model did not improve the model ($\Delta\chi^2 = 0.66$, $\Delta df = 1$, $p > .05$, *ns.*), as participants were as fast to read the subject-verb region when it was preceded by the underspecified connective *et* as they were when the relation expressed was temporal ($M = 796.30$, $SD = 327.71$) or causal ($M = 783.22$, $SD = 336.14$) ($\beta = 11.83$, $SE = 35.21$, $p > .05$, *ns.*), as shown in Figure 4.

Implicit subset

In the **subject-verb region**, adding Relation to the simplest model – which only included items and participants as random effects – marginally improved the model ($\Delta\chi^2 = 2.84$, $\Delta df = 1$, $p = .09$). This model showed that, when no connective was present, participants tended to read the subject-verb region faster when the relation expressed was temporal ($M = 788.13$, $SD = 346.71$) rather than causal ($M = 845.65$, $SD = 339.99$) ($\beta = -58.33$, $SE = 34.51$, $p = .09$), as shown in Figure 3.

In the **complement region**, adding Relation to the simplest model did not improve the model ($\Delta\chi^2 = 0.66$, $\Delta df = 1$, $p > .05$, *ns.*), as participants were as fast to read this region when the relation expressed was temporal ($M = 826.94.13$, $SD = 327.46$) as they were when it was causal ($M = 811.05$, $SD = 376.61$) ($\beta = 28.63$, $SE = 35.58$, $p > .05$, *ns.*), as shown in Figure 4.

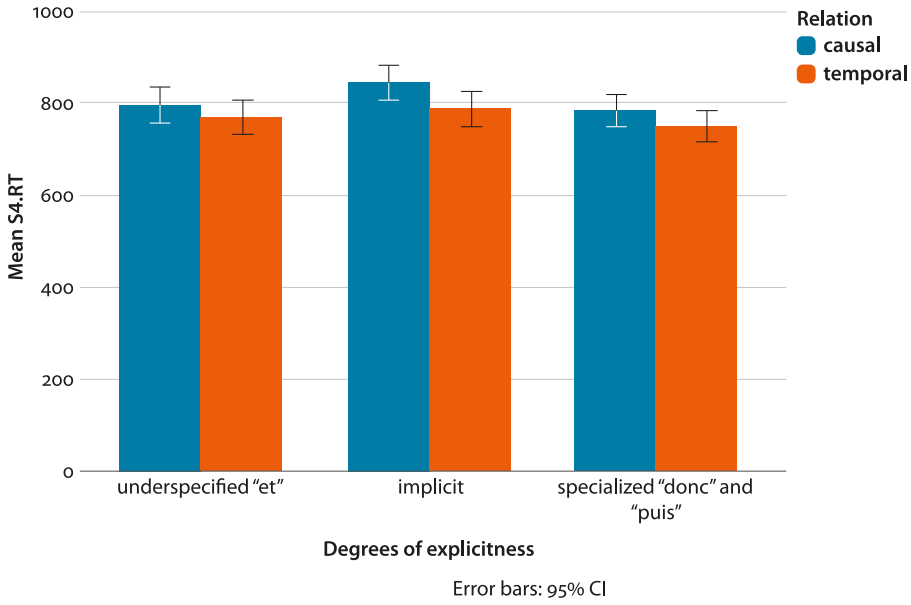

Figure 3. Mean RTs (ms) for implicit and underspecialized cases in the subject-verb region

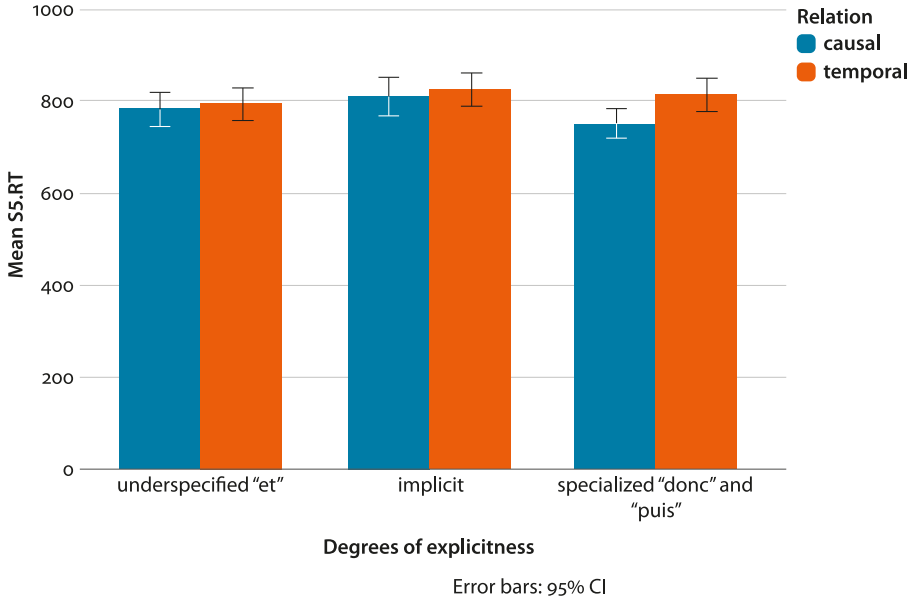

Figure 4. Mean RTs (ms) for implicit and underspecialized cases in the complement region

3.2.5 *Discussion of the results*

Table 4 summarizes our findings on causal and temporal relations for all levels of explicitness.

Table 4. Summary of the findings in terms of processing time in different experimental conditions

Relation	The subject-object region	The complement region
Causal	– Processing times in *donc* and *et* are shorter than in the *implicit* condition	– Processing times in *donc* and *et* are shorter than in the *implicit* condition
Temporal	– Processing time in *puis* is shorter than in the *implicit* condition – Processing time in *puis* is similar to the *et* condition – Processing time in *et* is similar to the *implicit* condition	– Processing times in *puis* and *et* are shorter than in the *implicit* condition

The results from our **first analysis** showed a main effect of Degrees of explicitness, as participants read the experimental items faster when the relation (temporal or causal) was marked explicitly with a connective, independently of its specificity (specified *puis* and *donc* or underspecified *et*). This result held for both regions of interest: the subject-verb and the complement region. The results also showed that there is no statistical difference between participants' mean reading times with respect to the type of relation presented: temporal and causal relations were processed at equal speed. At this coarse-grained level, the findings do not corroborate the Causality-by-default hypothesis, since the causal relations were not processed faster than the temporal ones. This may be due to the specific choice of our experimental material. For a 'fairer comparison' between causal and non-causal relations, we tested short narratives involving schematic types of underlying relations, rather than relations that are dissimilar from a structural point of view (cf. Sanders & Noordman 2000). The Facilitating Connective hypothesis was confirmed, as the use of the connective serving to express a given relation explicitly (rather than its implicit expression) speeded up the processing time of the two regions immediately following the connective.

The results from the **second analysis** offer a finer-grained picture. For **causal relations**, we observed the facilitating effect of the explicit marking, such that the subject-verb regions following the specialized connective *donc* as well as the underspecified connective *et* were read faster than the implicit versions. However, the difference between *donc* and *et* was not statistically significant. Similar results were found for the complement regions. Therefore, we can conclude that the Facilitating

Connective hypothesis was confirmed, but the Specialized Connective hypothesis was not corroborated by the results from the causal relations subset.

Regarding the **temporal relations**, we observed for the subject-verb region that the relations expressed with the specified connective *puis* were treated significantly faster than the cases where the relations were left implicit. For the underspecified connective *et*, we did not find a difference between either *et* and *puis* or *et* and the implicit expression of the temporal relation. In the complement region, we observed a small speed-up for the connective *et* with respect to the two other options. The complement region was read significantly faster when the relation was conveyed with the connective *et* than when it was left implicit; however, there was no significant difference observed between *et* and *puis*. Hence, for the temporal relations, the Facilitating Connective hypothesis was partly confirmed in the subject-verb region, and fully confirmed in the complement region. Comparing cases when the relation (**temporal and causal**) was left **implicit**, we observed a tendency for quicker processing of temporal implicit relations over causal ones in the subject-verb region. This tendency did not persist in the complement region. Therefore, we can say that this tendency reinforces the failure to confirm the Causality-by-default hypothesis presented earlier. As far as the underspecified connective *et* is concerned, there is no significant difference between its temporal and causal interpretations, whether in the subject-verb region or the complement region. If the Causality-by-default hypothesis had prevailed, we would expect the causal interpretation of *et* to take less time than its temporal interpretation.

4. Discussion and conclusions

The aim of this study was to investigate how different degrees of explicitness affect the processing of discourse relations. Our self-paced reading experiment confirmed a general facilitating effect of the linguistic marking for both temporal and causal relations, by contrast with their implicit expression. However, the results did not provide evidence in favour of the Causality-by default hypothesis. We discuss these two findings in turn below.

Concerning the role of the connective, the results of the self-paced reading experiment provided clear confirmation of the Facilitator Connective hypothesis for causal relations, as the facilitating effect was present in the two regions immediately following the connective (the subject-verb and the complement region). As far as temporal relations are concerned, the confirmation is less straightforward. Although the explicit marking of temporal relations facilitates processing more than their implicit expression in the subject-verb region, the difference is only statistically significant for the specialized connective *puis* 'then'. Nevertheless,

both the specialized *puis* and the underspecified *et* 'and' accelerate processing in the complement region, compared to the implicit expression of temporal relations. Hence, we can conclude that the facilitating role of the connective – be it the specialized *donc* 'so' or the underspecified *et* 'and' – is clearly observable for causal relations in both regions of interest.

Nonetheless, in the case of temporal relations, the Facilitator Connective hypothesis was only partially confirmed – that is, only for the specialized connective *puis*. This replicates the results of a previous study in French, in which the facilitating role of two specific French connectives (*puis* and *ensuite* 'then') was confirmed for the processing of short narratives (Grisot & Blochowiak 2019). The Specific Connective hypothesis was not verified for any type of relation: there is no processing difference between the connective *puis* and temporal *et*, nor between the connective *donc* and causal *et*. As such, both specialized and underspecified connectives are effective enough to speed up the integration of the causal relation. In contrast, only the connective specialized for temporal relations (*puis*) increases the rapidity of processing on the segment immediately following the connective, while the effect of the underspecified *et* is observable only on the next (complement) segment.

In view of our results, the following questions arise: why was the Specific Connective hypothesis not confirmed, and why was the Facilitator Connective hypothesis fully verified for causal relations, but only verified for the specialized connective *puis* in the case of temporal relations? The answer probably appeals to the specificity of the connective *et*, which is used to indicate many different types of relation, and is highly polyfunctional at a discourse level across numerous languages (see Crible et al. 2019 for a recent study involving five different languages). With respect to temporal relations, it behaves in two different ways, expressing both forward and synchronous temporal relations (Blochowiak & Castelain 2018; Grisot & Blochowiak 2021). The results of Grisot & Blochowiak (2021) corpus study revealed that the underspecified connective *et* is used equally frequently to express forward (48.6%) and synchronous (50.5%) temporal relations, whereas the presence of a specialized connective significantly increases the probability of a forward (64.2%) temporal relation rather than a synchronous relation (30.5%). This frequency result might explain why *et* cannot facilitate processing (as we found in the self-paced reading experiment): its content does not uniquely indicate forward temporal relations (as does the specialized connective *puis*).

At the same time, Grisot & Blochowiak (2021) found that the connective *et* is actually used more frequently than the specific connective *puis* to mark forward temporal relations: of a total of 124 cases of explicit forward temporal relations, the specific connective *puis* is used in 20% of cases (25 occurrences) vs. the underspecified connective *et*, which is used in 41% of cases (52 occurrences). Using spoken

and written data, Crible (2017) also found that the connective *et* is actually used more frequently to express temporal relations (24 occurrences) than the specific connective *puis* is (12 occurrences). With this in mind, we suspect that the particular nature of temporal *et* (its dual behaviour and its higher frequency than specific *puis*) overrides a possible gradation between degrees of explicitness that could be observed *a priori* between specialized connectives and the underspecified connectives. By contrast, this phenomenon applies only very marginally to causal relations (as discussed in Blochowiak & Castelain 2018; Blochowiak 2014), which is why our results on the processing of causal relations do not parallel those found for temporal relations.

Regarding the comparison between the two types of relations studied, the results from our processing experiment do not corroborate the Causality-by default hypothesis, as we did not find significantly shorter reading times for causal relations in the implicit condition, nor in either of the two levels of explicitness (specialized or underspecified connective). How can this be explained? As we mentioned previously, we sought to establish a 'fairer comparison' from the start, which is why we constructed our stimuli to have schematic sequences of events involving mental schemas in both temporal and causal experimental items. We deemed this necessary because causality, especially in the short narratives that we used, resorts to the causal type of mental schemas (Carston 2002) that reflect readers' encyclopaedic knowledge stored in the form of causal rules or laws (Cozijn et al. 2011; Blochowiak 2014). This aspect of causality greatly contributes to a special nature of causal relations. To balance this 'advantage' of causality, we used short temporal stories for which temporal schemas can also be established. Within this setup, the differences of processing between causal and temporal relations are not statistically significant; we even observed a tendency for shorter reading times of temporal relations over causal ones when they are left implicit.

As mentioned in Section 2.2, the differences between causal and additive (list-like) relations can be characterized in terms of connectedness. Causal or problem-solution relations have more organizational components resulting in a better organization of the discourse than the collection type of relations, such as additive, list-like relations (Meyer & Freedle 1984). Some models of discourse processing take this information into account, claiming that readers spontaneously search for information with high explanatory potential – causality in problem-solution configurations being a typical example – as their strategy is to construct representations composed of maximally connecting pieces of information (Graesser, Singer & Trabasso 1994; van den Broek 1990). In other words, the fact that causality is processed faster than additivity could be considered a result of their very different potential to connect information in the discourse. This conclusion was also put forth in Sanders & Noordman (2000: 54), who compared

directly causal and additive relations. However, this phenomenon cannot explain our results, given that we did not test the problem-solution type of causal relations but mere cause-consequence configurations which are not supposed to trigger expectations related to discourse connectedness (cf. Mulder 2008 for a detailed discussion).

We propose that our results can be explained by the accessibility of the content of a given relation, as advocated by Relevance theory. As we discussed in Section 2.1, Carston (1993, 1993, 2002) put forth a proposal according to which the availability of causal and temporal relations is directly related to the degree of accessibility of the mental schemas or cognitive scripts driving the comprehender's process of interpretation. Indeed, the degree of availability of causal and temporal relations we tested was similar because our experimental items were based on the schemas of sequences of events (temporal and causal) involving readers' schematic knowledge of the world. The general pragmatic principle of relevance applies here, and can further elucidate the results. According to this principle, the more available the contextual assumptions established by readers via mental schemas, the easier the accessibility of the information, regardless of the type of relation. Therefore, the general conclusion is that – more than causality per se, as in the Causality-by-default hypothesis – it is the degree of accessibility of a given relation by means of mental schemas or cognitive scripts that counts the most.

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