

Processing Discourse: Evidence from a Semantics-Informed Psycholinguistic Study

O processamento do discurso: contributos de um estudo psicolinguístico de base semântica

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Abstract

This work consists of a psycholinguistic study on discourse relations (DRs) in European Portuguese (EP), framed by a semantic basis. The aim of the article is to provide an updated theoretical framework on the main key aspects related to the study of the psycholinguistic processing of DRs, as well as to share some recent data on an *online* processing task of DRs in EP. In the first part of the article, we report the main themes related to processing of DRs, addressing aspects related to the processing of lexical connectives, issues related to causality and continuity, as well as issues related to linear sentence order. In the second part of the article, recent data on the study of processing of DRs in EP are presented and discussed.

Keywords: Psycholinguistic processing of discourse, discourse relations, psycholinguistic-semantics interface, online processing, causality.

Resumo

O presente trabalho consiste num estudo psicolinguístico sobre as relações discursivas (RDs) em Português Europeu (PE), enquadrado por uma base semântica sobre o tema. O objetivo do artigo é fornecer um enquadramento teórico atualizado sobre os principais aspetos-chave relacionados com o estudo do processamento psicolinguístico das RDs, bem como partilhar alguns dados recentes sobre uma tarefa de processamento *online* das RDs em PE. Na primeira parte do artigo damos conta das principais temáticas relacionadas com o processamento das RDs, abordando questões relacionadas com o processamento de conectores lexicais, questões relacionadas com causalidade e continuidade, bem como questões relacionadas com a ordenação linear da frase. Na segunda parte do artigo são apresentados e discutidos dados recentes sobre o estudo do processamento das RDs em PE.

Palavras-chave: Processamento psicolinguístico do discurso, relações discursivas, interface psicolinguística-semântica, processamento *online*, causalidade.

1. Introduction

This work presents a psycholinguistic study on discourse relations (henceforth DRs) in European Portuguese (henceforth EP), framed within a semantic basis. The aim of the article is to provide an updated theoretical framework on the main key aspects related to the study of the psycholinguistic processing of DRs, as well as to report recent data from an online processing task of DRs in EP.

The structure of the article is as follows: in the first three sections we review the main themes related to the processing of DRs, addressing questions related to the processing of lexical connectives, and discussing main theories on discourse processing - namely the causality and continuity hypotheses - as well as questions related to linear sentence order and linear cause-effect ordering. Additionally, we also present and discuss current psycholinguistic evidence on DRs in EP.

In the second part of the article, data from a study on the processing of DRs in EP are presented and discussed. Reporting on a subset of a previous in-press study, we present a further analysis of a t-test that shows differences in the processing of DRs attributed to the role of causality (its presence or absence) and the directionality of the establishment of the DR.

We conclude briefly with the main considerations and future directions.

2. Processing discourse relations

DRs correspond to the logical links established between parts of an utterance (Asher & Lascarides, 2003; Zufferey & Degand, 2024). They play a central role in representing the world and its events, and in representing the organization of discourse. DRs correspond to the meaning that emerges from the relations between two discourse units. They are pervasive in language use as they arise from sequences of utterances, which may correspond to clauses, sentences, or dialogue acts. They can occur in extended texts, thereby explicitly contributing to cohesion and coherence, and they are also present in clause sequences, such as in a complex sentence with connectives as illustrated in example (1):

(1) John went to the doctor *because* he felt ill.

The concept of DRs emerges in Semantics to explain the meaning links established between discourse units. Their semantic definition can be approached from multiple perspectives. On the one hand, proposals may emphasize speaker intentionality (Mann & Thompson, 1988) or the cognitive operations triggered by the speaker (Sanders et al., 1992), treating DRs as cognitive entities with psychological reality. On the other hand, approaches, such as *Segmented Discourse Representation Theory* (SDRT) (Asher & Lascarides, 2003), view DRs as descriptive and operational constructs that allow the formal analysis of discourse structure.

DRs are central to the cognitive representation of text and, consequently, to its interpretation. Therefore, they have been studied not only in Semantics, but recently also in Psycholinguistics through different approaches and methods. In the following sections, we review some of the main findings on the processing of DRs, reflecting its continued prominence as a research topic.

2.1. The role of connectives in the processing of discourse relations

DRs often co-occur with linguistic markers, such as cue phrases or connectives, which guide the reader through the inferential process. Although recent corpus evidence indicates that DRs are more frequently signaled by a wide

variety of signals other than connectives (Das & Taboada, 2018), it remains important to examine findings related to the role of connective in the psycholinguistic processing of DRs, as these provide key insights into the cognitive mechanisms underlying DR interpretation.

On the one hand, evidence reviewed by Zufferey and Degand (2024) demonstrates that connectives have an immediate effect on discourse processing by speeding-up local processing. Additional roles attributed to connectives in *online* processing involve expectations reversal (mainly by concessive connectives) or expectations raising (by contrast connectives). Moreover, speakers integrate the information provided by all sorts of connectives thus showing the advantage of these signals in the processing of DRs.

On the other hand, Kleijn et al. (2019) examine whether the facilitative effect of causal connectives also extends to *offline* comprehension. Using a *cloze task*, they demonstrate that the insertion of a causal connective, although it may facilitate processing, does not substantially improve text comprehension. Their results corroborate the hypothesis for a preference of processing of causality (see next Subsection), but they critically provide novel evidence that this facilitative effect, namely the one brought by the connective, is relatively limited when comprehension outcomes are considered in isolation. In their study, causal connectives yield only a small effect on comprehension, despite their robust influence on *online* processing measures. With respect to additive DRs, Kleijn et al. (2019) even show that the presence of a connective may reduce *offline* comprehension. Additive connectives may impose an unnecessary focus on the juxtaposition of situations. As the authors note, “rather than taking two consecutive segments as sharing a (sub)topical focus, an interpretation invited by a simple juxtaposition, additive connectives may have invited readers to look at this relation more closely” (Kleijn et al., 2019, p. 458). For temporal relations, the addition of a connective does not appear to either facilitate or hinder comprehension (Kleijn et al., 2019, p. 458). This finding suggests that tense and aspectual semantics may play a more decisive role in processing than explicit connective marking in such cases. Kleijn et al. (2019) further show that the effects of connectives emerge primarily in difficult texts and do not interact with educational level or reading proficiency. Easy texts, by virtue of their conceptual simplicity, do not benefit from connectives, whereas difficult texts, being more complex, do so regardless of reader characteristics.¹

In sum, research indicates that connectives exert a local and incremental facilitative effect on sentence and text processing. However, they are not essential for the interpretation of the DR, consistent with corpus-based observations that many DRs are signalled by alternative (syntactic, semantic or even graphical) signals (Das & Taboada, 2018).

2.2. Causality and continuity in the processing of discourse relations

Within psycholinguistic research on the processing of DRs, two prominent hypotheses have emerged. The Continuity Hypothesis (henceforth CH) (Asr & Demberg, 2012; Segal et al., 1991), which emphasizes the role of continuity assumptions in linking events across clauses; and the Causality-by-Default Hypothesis (Sanders, 2005), which proposes that causal relations constitute a preferred interpretive strategy in constructing coherence.

The CH posits that readers show a preference for interpreting sequences of sentences in a temporally and conceptually continuous manner. Empirical evidence – from experimental settings of text interpretation, such as Segal et al. (1991), and from corpus-based perspectives, such as Asr and Demberg (2012) – supports this claim, demonstrating that readers process temporally forward and additive DRs more efficiently than when contrasting

¹ For the role of individual differences, see Scholman et al. (2024), who show that factors such as linguistic experience, general reasoning ability, degree of exposure to written language, and educational background may modulate the processing of DRs at the individual level. In addition, Marchal et al. (2022) emphasize the importance of world knowledge, in particular domain knowledge and individual inferential capacity, in shaping discourse interpretation.

information is present. In contrast, DRs that involve contrastive shifts are typically more complex due to the discontinuities they introduce (Asr & Demberg, 2012; Segal et al., 1991). Consequently, readers benefit more when contrastive relations are linguistically marked compared to additive relations as we already mentioned in the previous section (cf., Kleijn et al., 2019). The CH is further supported by findings that discontinuous DRs tend to require explicit linguistic marking more often than continuous DRs (Asr & Demberg, 2012). However, recent work by Das and Egg (2023) suggests that when multiple dimensions of discourse are considered, the CH alone cannot fully account for observed patterns. This indicates that while temporal and causal continuity might facilitate processing, other factors, such as semantic coherence, topical structure, and information density, also play a role. Nevertheless, the CH aligns conceptually with the Uniform Information Density Hypothesis, which posits that speakers tend to distribute information evenly across a discourse to optimize processing efficiency (Levy & Jaeger, 2007). Continuous sequences often correspond to smoother information flow, reducing local spikes in processing load, whereas discontinuous or contrastive DRs create local information peaks. More importantly, continuity, in the sense of Segal et al. (1991), refers to the maintenance of the same frame of reference across sentences, i.e., subsequent unfold of the same topic without shifts in perspective, a definition that easily matches the formal description provided by Asher and Lascarides's (2003) for temporal DRs such as Narration.

Considering now the Causality-by-Default Hypothesis, the studies reviewed by Sanders (2005) and others (see also Zufferey & Degand, 2024) consistently show that causally related information is typically recalled more accurately and processed more quickly in experimental settings. This type of evidence gives rise to what Sanders (2005) terms the Paradox of Causal Complexity: although causal DRs are cognitively more complex (as demonstrated in studies on child language acquisition and development of DRs), they are nevertheless processed more efficiently and retained more robustly. To account for this paradox, Sanders (2005) draws on Asher and Lascarides (2003) principle of Maximizing Discourse Coherence, arguing that comprehenders exhibit a preference for causal DRs because they strive to connect information in a continuous and coherent manner. Nevertheless, findings from corpus-based studies complicate this picture. Asr and Demberg (2012), and especially Hoek et al. (2017), suggest that the predictions of the Causality-by-Default Hypothesis are not straightforwardly reflected in corpus data. This leads Hoek et al. (2017) to introduce the notion of cognitive complexity, thereby shifting the discussion from causality as a default preference to the broader question of how different DRs vary in their processing demands.

Causality in sentence processing is, thus, a complex but pervasive phenomenon. To illustrate this, we will mention contexts where causality is linguistically implicit, that is, when the linguistic structure invites the speaker to infer which event is the cause (reason or motivation) of some other event without the use of a lexically marked expression for causality (e.g., a connective). To this matter see examples (2) and (3):

(2) Mary *praised* John when *he/?she* did well on the exam.

(3) Mary *blamed* John when *#he/she* forgot the documents.

In (2), the subordinate clause is typically interpreted as referring to *John*, demonstrating that the verb *praise* biases an interpretation where the complement of the verb (and not the subject) is assigned the result for the reason of the eventuality present in the subordinate clause. In (3) the subordinate clause is typically interpreted as referring to *Mary*, showing that, on the contrary, verbs like *blame* carry an implicit causality bias toward the subject to the verb (cf., Hartshorne, 2014). These examples illustrate that implicit causality allows speakers to predict the referents of subsequent clauses and anticipate the structure of events, even before all information is explicitly stated. By integrating several linguistic cues, speakers infer causal DRs, demonstrating that event interpretation relies not only

on background *a priori* assumptions about how actions and their causes unfold, but especially on linguistic knowledge (from thematic roles, grammatical gender, pronoun form and lexical compositional meaning, see Hartshorne, 2014; Wei & Knoerferle, 2023).

2.3. (Non-)Linear order in the processing of discourse relations

Research on implicit causality mentioned earlier (see previous section) has examined situations in which speakers know the referents but lack other causal marking than the verb. Alternatively, Gershman and Ullman (2023) and Lassiter and Franke (2024) investigated whether linguistic structure alone could guide causal inference when only associative relationships were present. Importantly, in these studies, causal interpretation was not explicitly encoded in the stimuli or arising from spontaneous interpretation; rather, participants were required to provide causal judgements on the basis of correlational statements, namely through forced-choice tasks. Thus, the results should be understood as evidence for systematically elicited causal implicatures, rather than as purely spontaneous causal interpretations in naturalistic comprehension settings. In experiments using non-words (e.g., *X is associated with Y*), participants systematically interpreted *X* as the effect and *Y* as the cause, imposing a default but cognitively unexpected effect–cause order that persisted even when discourse factors, such as informational structure, were manipulated. Differently, when adding minimal changes to the testing utterances to create expressions such as *X is associated with an increased probability of Y*, participants inverted the order by interpreting *X* as the cause. In further experiments, Lassiter and Franke (2024) still show that lexical semantics could override default cause–effect attribution: when the stimulus included the word *drug* such as in *Drug A is associated with B* the first referent (*A*) was interpreted as the cause, whereas when using *disease* as testing word the second entity (*B*) retained the status of cause. Additionally, coordination structures such as *X and Y are associated* prompted assignment of *X* as the cause.

These findings indicate that: (1) speakers attempt to infer causality even in purely correlational contexts, reflecting systematic preferences for causal reasoning; (2) linguistic properties interact with cause–effect assignment, potentially shaping participants’ interpretations and preferences for cause and effect roles.

Building on Raposo (2013), we will argue that participial constructions appear to convey a resultative state that arises from an event affecting an entity, whilst copular clauses describe a stable property that may reflect a prior change of state. In copular constructions with participles (e.g., *X is associated with Y*), the participial form (*associated*) could be highlighting *X* as the resultant state, which in turn may lead *Y* to be interpreted as the cause, aligning with behavioral tendencies observed in the previously mentioned experiments (Gershman & Ullman, 2023; Lassiter & Franke, 2024). Conversely, lexical cues such as *increased probability* in expressions like *X is associated with an increased probability of Y* appear to signal the effect, since a probability expression is more likely to refer to outcomes (effects) rather than causes, although causes themselves can also be presented as uncertain (i.e., probable) in certain contexts and typically through the use of lexical cues such as probability adverbs. Taken together, these tentative observations suggest that interactions among temporo-aspectual features, lexico-compositional semantics, and linear order of arguments in the sentence may contribute to the assignment of cause and effect in purely correlational contexts.

Moreover, these results suggest that speakers are capable of intuitively constructing a dual DR of both Explanation and Result by altering the linear order of the arguments (cf., Asher & Lascarides, 2003). This duality

reflects deep, unconscious linguistic analysis, in which grammatical, aspectual, temporal, lexical, and linear-order cues interact to shape causal interpretation.²

Temporal (semantic) relations and the linear ordering of those in the sentence similarly impact processing. Münte et al. (1998) and Politzer-Ahles et al. (2017) demonstrated that reverse temporal sequences (i.e., a linear ordering of e_1 - e_2 such as with sentences beginning with the connective *before*) are more difficult to process and elicit increased frontal negative ERPs compared to sentences that follow chronological (iconic) order (e_1 - e_2 with connectives like *after*). Their results show that comprehension of temporal expressions becomes more effortful when linear order in discourse (the “order-of-mention” according to Politzer-Ahles et al., 2017) does not match the actual temporal (semantic) ordering of the events. While initially attributed to working memory constraints, this difficulty may also reflect inhibitory processes: readers must suppress a more accessible, isomorphic event model when processing reversed order, highlighting the interaction of memory and executive control in the processing of discourse (Münte et al., 1998; Politzer-Ahles et al., 2017).

This interpretation is also compatible with corpus-based analyses of DRs. Asr and Demberg (2012) distinguish between ordered and reversed DRs, depending on whether the DR presents a cause-effect or effect-cause order. In the case of temporal backward DRs such as Reason, they show that speakers frequently resort to reversed argument order (effect-cause) so as to preserve the temporal sequence of the described events. According to the authors, “there are always more ordinal modifications (the reversed presentation) when a backward relation of any type is being expressed”, leading them to conclude that, even in the presence of explicit discourse cues, speakers tend to keep the textual order of the arguments aligned with the temporal order in which the associated events occurred (Asr & Demberg, 2012, p. 2680).

Cross-linguistic corpus evidence further supports the interaction between temporal ordering and discourse structure. Mendes et al. (2023) show that languages differ in the extent to which they reverse the linear order of the arguments of temporally backward DRs. In Turkish, approximately 26% of explicit Reason DRs are expressed through reversed argument order (effect-cause), beginning with the connective. The authors interpret this preference as reflecting a tendency to preserve the iconic linear order of the eventualities, despite the backward semantic orientation (effect-cause) of the DR. By contrast, English, Lithuanian, and Portuguese show no comparable tendency to reverse the order of the arguments in Reason DRs. These cross-linguistic findings suggest that preferences for linear ordering result from the interaction between the semantics of the DR and language-specific discourse conventions.

In developmental psychology, Tecwyn et al. (2020) additionally show that both children and adults mentally reorder events so that a cause precedes an effect, even when the actual temporal sequence of the experiment probe is reversed. These results highlight that causal reasoning can actively restructure the mental representation of temporal sequences.

Taken together, these findings underscore that both temporal and causal relations are tightly intertwined. Matching temporal (semantic) relations of successivity with a linear (iconic) ordering of the events in the sentence seems to facilitate both processing and inference, whereas a reversed ordering of the events in the sentence imposes greater cognitive demands. Nevertheless, speakers seem capable of mentally reordering events to maintain a coherent causal chain. Temporal (semantic) relations and their surface ordering in the sentence might thus function both as a processing facilitative factor and as a heuristic for inferring causal structure.

² Neurocognitive evidence further supports the relevance of linear cause-effect order with Liang et al. (2016) showing that word pairs presented in a cause-effect order evoked smaller N400 amplitudes than the inverse pairs. This result nevertheless contrasts with some of the main findings of both Gershman and Ullman (2023) and Lassiter and Franke (2024) discussed.

3. Psycholinguistic research on discourse relations in European Portuguese

DRs have long been investigated within the semantic tradition of Portuguese linguistics (Cunha & Silvano, 2009; Móia & Viotti, 2004; Oliveira et al., 2010; Silvano, 2007, 2010, 2012), as well as in corpus-based studies of Portuguese (Mendes et al., 2023; Silvano et al., 2023; Silvano et al., 2026; Tomaszewska et al., 2024; Zeyrek et al., 2024).

More recently, research on the psycholinguistic processing of DRs has gained prominence, as evidenced by an increasing number of oral communications presented at national scientific meetings. This growing body of work includes studies on the processing of explicit and implicit DRs (Falé et al., 2024), as well as investigations targeting specific constructions, such as gerundive clauses (Gomes et al., 2024), which have yielded relevant insights into the cognitive mechanisms underlying discourse interpretation. In this context, Magalhães et al. (in press) report findings from a self-paced reading experiment conducted as part of a broader research program on the processing of DRs in EP.

In their study of complex sentences with adverbial subordination introduced by the connective *quando*, Magalhães et al. (in press) aim to examine potential differences in the processing of extrinsic and intrinsic DRs. This distinction is based on Cunha and Silvano (2009), who differentiate between DRs that maintain the same frame of reference (topic) across clauses without establishing DRs beyond temporo-aspectual sequencing, and DRs that encode a causal link between situations. Using a self-paced reading task, the authors identify processing differences associated with causality, linear clause order, cause–effect sequencing, and temporal relations. The self-paced reading results reveal a facilitative effect in the processing of DRs of Result. Accordingly, the authors advance the hypothesis that processing might be preferential when the sentence instantiates a causal connection and when this connection is presented with the cause preceding the effect. This configuration aligns the temporal (semantic) successivity of events with their linear (iconic) ordering in the sentence. The results further show that the connective *quando* marks a relevant transition point in sentence processing by reducing reading times (henceforth RTs) at the point of encountering the connective and by accelerating processing toward the final stages of the sentence. This pattern can be interpreted as evidence for the localizing function of *quando*-clauses, as proposed in previous literature (cf., Silvano, 2010). The relevance of this latter finding for discussions concerning the directionality involved in the establishment and annotation of DRs is to be explored in future work.

Taken together, the findings of Magalhães et al. (in press) suggest that the processing of DRs in EP may be sensitive to causal structure, temporal sequencing, and linear order of clauses in the sentence. The results converge with broader psycholinguistic evidence showing that causal and temporal successivity facilitate comprehension, while connectives such as *quando* play a crucial role in guiding incremental interpretation. These observations contribute to the emerging picture of the processing of DRs in EP and support the integration of both syntactic, semantic and cognitive perspectives in the study of DRs. Future research will be essential to refine these insights and clarify further questions.

4. Temporal values of *quando*-clauses

Quando-clauses are typically classified as temporal adverbial clauses and are therefore assumed to introduce a situation that serves to temporally locate the situation introduced by the matrix clause. However, unlike temporal clauses introduced by lexically specified connectives such as *depois de* ('after'), *antes de* ('before'), or *assim que* ('as soon as'), *quando*-clauses do not encode any specific temporal relation with the matrix clause. As a result, several temporal interpretations are available. In this respect, the classic examples discussed by Moens and

Steedman (1988, p. 15) and reproduced below show that *when/quando*-clauses allow for multiple temporal relations with the matrix clause.

- (4) When they built the 39th bridge a local architect drew up the plans.
- (5) When they built the 39th bridge they used the best materials.
- (6) When they built the 39th bridge they solved most of their traffic problems.

In Portuguese, the adverbial temporal clauses introduced by *quando* present particularly relevant semantic properties, especially because their interpretation depends on the aspectual nature of their constituents (Cunha, 2000; Cunha & Silvano, 2009; Silvano, 2007). Indeed, as illustrated in examples (7)-(10), the subordinate clause may establish different temporal relations with respect to the situation located in the matrix clause, including simultaneity (cf., (7)), posteriority (cf., (8)), anteriority (cf., (9)), and an iterative or habitual interpretation, conveyed by the use of *Preterito Imperfeito* in the sentence (cf., (10)).

- (7) Quando a Maria chegou, o João estava a cozinhar.
When Maria arrived, João was cooking.
- (8) Quando entrei no carro, abri as janelas.
When I got into the car, I opened the windows.
- (9) Quando me mudei para o Canadá, pedi a emissão do passaporte.
When I moved to Canada, I applied for a passport.
- (10) Quando tinha boas notas, a minha mãe oferecia-me um gelado.
When I had good grades, my mother would buy me an ice cream.

This flexibility arises because such clauses lack presuppositional features and because, as Cunha (2000) observes, the operator *quando* is semantically neutral, that is, it does not impose any obligatory lexical interpretation. As a result, *quando*-clauses allow for multiple semantic relations between the situations described in the sentence, depending on temporo-aspectual constraints, pragmatic inferences, linear order in discourse, and the speaker's world knowledge (Lobo, 2013). Consequently, in addition to lacking a fixed temporal interpretation, *quando*-clauses are not associated with a single DR but rather with a range of possible DRs (Silvano, 2007, 2010, 2012).

5. The present study

This study was initially designed to address two research questions that have guided the present work and related research (see Magalhães et al., in press):

- RQ1: Does the linear order of complex sentences containing adverbial subordinate clauses introduced by the connective *quando* affect the online processing of DRs?
- RQ2: Are extrinsic and intrinsic DRs in complex sentences containing adverbial subordinate clauses introduced by the connective *quando* processed differently during online sentence comprehension?

A psycholinguistic analysis was applied to a dataset collected using a self-paced reading (SPR) task implemented via PCIBex Farm (Zehr & Schwarz, 2018), employing a non-cumulative moving window paradigm as previously described (Magalhães et al., in press). The sample consisted of 113 participants ($M_{age} = 32.58$; $SD = 12.34$; 71 women; 101 right-handed), with varying educational backgrounds (ranging from secondary education to doctoral level) and reading profiles evenly distributed across three groups (<5 , $5-10$, >10 books read per year). The experiment did not involve any compensation. The experiment and the Informed consent were approved by the Ethics Committee of the Faculty of Arts and Humanities of the University of Porto (48/CEFLUP/2024), as well as by the Data Protection Unit of the University of Porto (0187/2024).

The results reported below correspond to a subset of participants who answered the comprehension question correctly. This question asked whether the sentence they had just read was acceptable, and positive responses were expected for experimental sentences compared to ungrammatical fillers. Only trials with correct positive responses were included in the analysis. RTs below 200 ms or above 2000 ms were excluded as outliers. The remaining data were log10-transformed to reduce potential skewness in the distribution and stabilize variance.

5.1. Materials

The test stimuli consisted of complex sentences with adverbial subordination using the connective *quando*, presenting four DRs: Inverted Narration, Narration, Explanation, and Result.

Each condition combined a specific DR (Inverted Narration, Narration, Explanation, Result) (see Table 1) with a specific order of clause presentation (Main-Subordinate: MainSub, or Subordinate-Main: SubMain). These conditions were chosen to reflect the two distinct groups of DRs: relations containing a causal link and relations that were inferred mainly through the combination of the eventualities in a determined temporal organization (see Cunha & Silvano, 2009) and were not fully crossed, i.e., not all possible combinations of DR and clause order were included. Consequently, the materials did not follow a fully factorial design (e.g., 2×2). Instead, the four DRs were treated as distinct levels of a single experimental factor and, for the present study, they were divided in two groups according to the positional linear order. Given this design, structures with different orders of main and subordinate clauses could not be directly compared. Therefore, only structurally equivalent conditions were compared: Explanation and Inverted Narration in the MainSub order, and Result and Narration in the SubMain order. The following analyses therefore refer only to these two groups of comparisons.

Furthermore, Explanation is not used here as a general label for causality. Rather, it refers to the specific DR defined in SDRT (Asher & Lascarides, 2003), whose dual is Result (see Table 2). In the present experiment, Explanation and Result are therefore treated as two distinct DRs, differing in the directionality of the causal relation (effect-cause vs. cause-effect).

The present study focuses exclusively on propositional (*de re*) causality (see Silvano, 2010), which is arguably less cognitively complex because the causal relation is established directly between the eventualities described in the sentence. This does not imply that world knowledge plays no role in interpretation; rather, it means that the DR can be identified primarily on the basis of propositional content and generic background knowledge. Within the two causal DRs addressed in the study, we do not distinguish between different subtypes of causality, such as physical versus psychological causality (Van den Broek, 1994), causal versus diagnostic relations (Traxler et al., 1997), or epistemic versus speech-act causality (Silvano, 2010). Instead, the experiment investigates propositional causal DRs more generally, whether they arise from lexical semantics (e.g., *push-fall*) or emerge compositionally through the interaction of the two eventualities, the connective *quando*, clause order, and general world knowledge.

All test sentences were controlled for length, segment structure and verb type (direct or indirect transitive). A total of 140 experimental items were distributed across eight lists together with 56 distractors. Due to design

constraints, one list contained fewer critical items than the others; however, this did not compromise condition balance, as all conditions were equally represented. Data were analyzed using a linear mixed-effects model, which accommodates variations in the number of observations. All items were constructed collaboratively and checked by an experienced semanticist.

Table 1

Test Stimuli

Condition	Discourse Relation	Linear order	Example
1	Inverted Narration (InvNarr)	MainSub	O rapaz ₁ cozinhou ₂ um bolo ₃ de maçã ₄ , quando, o irmão ₅ chegou ₆ , a casa ₇ , de tarde ₈ .
2	Narration (Narr)	SubMain	Quando, o rapaz ₁ chegou ₂ , a casa ₃ , de tarde ₄ , o irmão ₅ cozinhou ₆ , um bolo ₇ , de maçã ₈ .
3	Explanation (Expl)	MainSub	A planta ₁ , brotou ₂ , umas flores ₃ , novas ₄ , quando, a mulher ₅ , podou ₆ , os ramos ₇ , no verão ₈ .
4	Result (Result)	SubMain	Quando, a mulher ₁ , podou ₂ , os ramos ₃ , no verão ₄ , a planta ₅ , brotou ₆ , umas flores ₇ , novas ₈ .

Note. Examples are numbered according to the order in which stimuli are segmented in the self-paced reading task.

Table 2

Definition of DRs Addressed in the Present Study

Discourse Relation	Definition
Inverted Narration (α, β)	R holds if the constituents express eventualities that occur in the inverted sequence in which they were described. α and β share a contingent common topic, and the more informative the topic, the better the narration. <u>Spatiotemporal Consequence of Inverted Narration:</u> $\emptyset \text{Inverted Narration}(\alpha, \beta) \Rightarrow \text{overlap}((\text{prestate}(e_\alpha), (\text{poststate}(e_\beta))), \text{i.e., where things are in space and time at the end of } e_\alpha \text{ is where they are at the beginning of } e_\beta.$
Narration(α, β)	R holds if the constituents express eventualities that occur in the sequence in which they were described. α and β share a contingent common topic, and the more informative the topic, the better the narration (hence, narration is scalar). <u>Spatiotemporal Consequence of Narration:</u> $\emptyset \text{Narration}(\alpha, \beta) \Rightarrow \text{overlap}(\text{prestate}(e_\alpha), \text{Adv}_\beta(\text{poststate}(e_\beta))), \text{i.e., where things are in space and time at the end of } e_\alpha \text{ is where they are at the beginning of } e_\beta.$
Result	R connects a cause to its effect. $\emptyset \text{Result}(\alpha, \beta) \Rightarrow \text{cause}(e_\alpha, e_\beta)$
Explanation	R is the dual to result. <u>Temporal consequence:</u> (a) $\emptyset \text{Explanation}(\alpha, \beta) \Rightarrow (\neg e_\alpha < e_\beta)$ (b) $\emptyset \text{Explanation}(\alpha, \beta) \Rightarrow (\text{event}(e_\alpha) \Rightarrow e_\beta < e_\alpha)$

Note. Authors' compilation based on Silvano (2010).

5.2. Procedures

Participants were tested remotely via PCIBex Farm (Zehr & Schwarz, 2018). After providing informed consent and sociodemographic information in accordance with the General Data Protection Regulation requirements, they received on-screen instructions explaining the task. Only native speakers of EP were eligible to participate, and thus non-native speakers were instructed to exit the study. The experiment was implemented using PCIBex Farm and employed a self-paced reading task with a non-cumulative moving window paradigm, where sentences were initially masked and revealed word-by-word as participants pressed the spacebar, with previously read words becoming masked again. Participants were assigned to one of eight experimental lists containing both experimental items and fillers. Each item was followed by a binary comprehension question to ensure attention. A short practice phase with five items preceded the experiment. The full session lasted approximately 20 minutes. Data on RTs, answer to comprehension question, and sociodemographic variables were recorded for analysis.

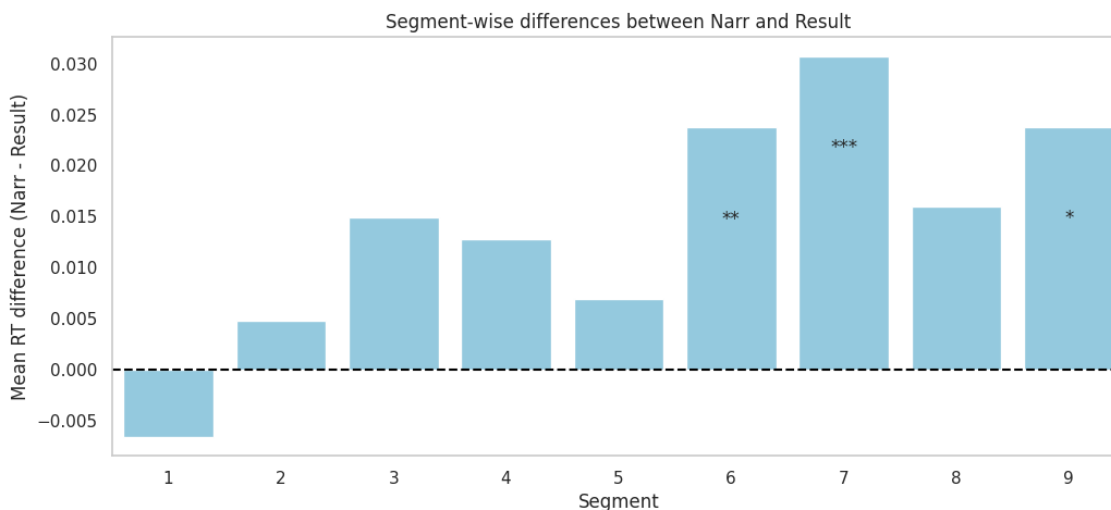
5.3. Results: Statistical analysis using t-test

The linear mixed-effects model described in Magalhães et al. (in press) revealed a facilitatory effect of the Result condition (see Section 3 above). To further examine differences between groups, a t-test analysis was conducted on two groups of DRs with similar syntactic structures: Inverted Narration vs. Explanation and Narration vs. Result.

The t-test results indicated that only the comparison of DRs in the SubMain order reached statistical significance ($t = 1.98$, $p = .047$, see Tables 3 and 4). Given the significant result for the Narration-Result group, an explanatory graph was generated using Python (see Figure 1).

Figure 1

Significant Differences of a t-test on the Narration–Result Group



Note. Figure 1 illustrates the significant differences of a t-test on the Narration–Result group (p value = .047) showing that Narration RTs increase as the sentence unfolds, particularly in the beginning of the second sentence (segment 6), the critical region (segment 7) and in the *wrap-up* region (segment 9). Example sentences: *Quando, o rapaz, chegou, a casa, de tarde, o irmão, cozinhou, um bolo, de maçã.* (Narr) vs. *Quando, a mulher, podou, os ramos, no verão, a planta, brotou, umas flores, novas.* (Result).

Figure 1 shows differences between the Narration and Result DRs. Differences are observable in the first segment of the second clause, in the critical region and *wrap-up* of the second clause (the main clause). Specifically, after processing the subordinate clause with *quando*, the main clause is processed faster when a causal link (Result) is established. Readers initially process the connective *quando* more quickly (lower RTs in Segment 1), but as the sentence unfolds, Narration requires more sustained processing.

This sustained load in later segments suggests that causal relations (Result) may be cognitively easier to integrate than purely temporal or narrative relations (Narration), although the undetermined temporal value of *quando*-clauses (see Section 4) could also help explain the extra processing time to interpret the temporal ordering of the situations. Segment 1 is processed faster, possibly functioning as a cue for event localization. Importantly, these results align with theories of discourse comprehension proposing that causal coherence relations are easier to establish than purely temporal or narrative ones. The faster processing of Segment 1, introduced by *quando*, highlights its function as a localizing marker for subsequent events, and having a salient rhetorical link appears easier to integrate than a purely temporal one.

The first segment of the second clause, the critical region and the *wrap-up* region indicate that additional cognitive resources are recruited when causal information is absent. Differences in these regions (see Figure 2 below for a detailed view) suggest that DR establishment occurs *in situ*, as the second clause begins to be processed. However, effects in the *wrap-up* region may also reflect final integration processes, such as linking the second event to its temporal or localizing antecedent (*quando*-clause), or the presence/absence of causality.

Overall, the increased incremental load in SubMain conditions (Narration and Result) indicates that when the temporal locator is already available, the DR can be established *in situ*, supporting efficient incremental processing.

Figure 2

Zoomed-in Illustration of RTs Differences According to Sentence Segment in Narr – Result Group

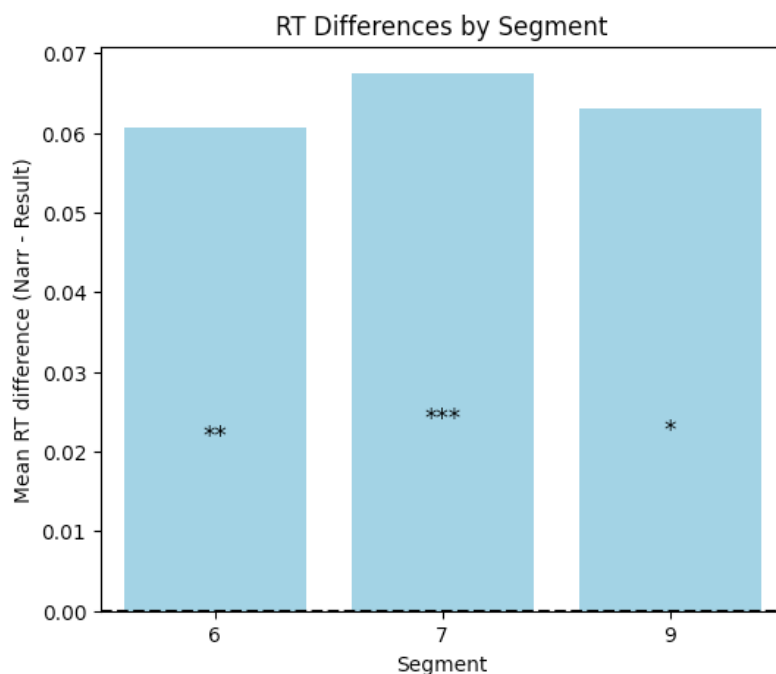


Table 3

T-test on the Inverted Narration–Explanation Group

Independent Samples T-Test

Independent Samples T-Test

		Statistic	df	p	Mean difference	SE difference
RT_Seg	Student's t	0.366 ^a	8864	0.714	0.00407	0.0111

Note. $H_0: \mu_{Expl} = \mu_{InvNarr}$

^a Levene's test is significant ($p < .05$), suggesting a violation of the assumption of equal variances

Note. Results of the t-test on the Inverted Narration-Explanation group without statistical significance (p value = .714).

Table 4

T-test on the Narration–Result Group

Independent Samples T-Test

Independent Samples T-Test						
		Statistic	df	p	Mean difference	SE difference
RT_Seg	Student's t	1.98 ^a	8918	0.047	0.0214	0.0108

Note. $H_0: \mu_{\text{Narr}} = \mu_{\text{Result}}$

^a Levene's test is significant ($p < .05$), suggesting a violation of the assumption of equal variances

Note. Results of the t-test on the Narration-Result group with statistical significance (p value = .047).

5.4. Discussion

The results reported above contribute to the broader discussion by linking sentence structure to the establishment of the DR. Specifically, sentences beginning with *quando* appear to allow incremental DR establishment, with the subordinate clause guiding the interpretation of the main clause.

From a theoretical perspective, Silvano (2010, 2013) notes a tendency in Semantics to assume that, in adverbial subordination with *quando*, the main clause is interpreted first, but only relative to the localization provided by the subordinate clause. This creates a kind of interpretive loop: the subordinate must already be partially processed for the main clause to be integrated. A relevant psycholinguistic question, then, is whether SubMain and MainSub orders differ in intermediate and final integration costs.

Our data suggest that SubMain orders exhibit a more incremental processing pattern, with intermediate integration costs reflecting the initial processing of the temporal/causal locator (*quando*), followed by interpretation of the main clause. This supports the idea that the subordinate clause functions as a localization cue, influencing the incremental establishment of the DR.

Additionally, previous studies examining at-issueness - that is, whether a clause contributes to the main point of a sentence - provide relevant insights for the present discussion. Frazier and Clifton (2005) argue that temporal adverbial clauses are unlikely to host at-issue content. One possible explanation is that, because such clauses typically function as locators of events, they do not usually convey the central informational contribution of the sentence. Related findings are reported by Wilke and Hoek (2024), who show that clauses located at the Right Frontier (see Asher & Lascarides, 2003) are more likely to be interpreted as hosts for antecedents and therefore as at-issue, whereas clauses that are not at the Right Frontier (e.g., sentence-initial relative clauses in the author's study) are less likely to receive such interpretations. Their results indicate that both clause position and clause type influence the at-issue status of clauses within sentences.

These observations align with the predictions of the Right Frontier Constraint (Asher & Lascarides, 2003, Wilke & Hoek, 2024). When multiple clauses are available at the Right Frontier, clauses in sentence-final position are more likely to host at-issue content. This tendency is further modulated by clause type, such that matrix clauses in final position are particularly likely to be interpreted as conveying the main point of the sentence.

Although these findings were obtained in different empirical contexts, they also support the interpretation of the results obtained in the present study. They are consistent with what is observed in the plot above: in SubMain constructions, if the main clause is more likely to carry the at-issue content, it is also more likely to function as the primary attachment site for subsequent DRs. Under this configuration, the subordinate clause assumes a more restricted role as it is expected to function primarily as a locator that establishes the conditions for interpreting the main event. In this sense, the subordinate clause provides the starting point for the discourse relation, anchoring the interpretation of the subsequent clause. In adverbial constructions with *quando*, this could typically correspond to a locating function, whereby the subordinate clause provides the temporal location for the eventuality described in the main clause. The subordinate clause therefore initiates the DR, while the main clause constitutes the main point of the sentence and remains available for further attachment.

Furthermore, the results reported by Cozijn et al. (2011) show a pattern similar to the one observed in the t-test analysis of our data. In their study, readers accelerate their RTs immediately after encountering the connective (*because*), a pattern interpreted as reflecting propositional integration, and subsequently slow down in the final segments of the sentence, where world-knowledge inferences are likely to occur.

A comparable incremental and data-driven processing pattern is visible in our results. This suggests that the DR begins to be established locally as soon as readers are able to connect the eventuality introduced in the clause to the preceding situation. Importantly, this pattern appears to be more pronounced in SubMain conditions, which may reflect the role of *quando* in initiating the establishment of the DR. It should be noted, however, that different results might be obtained with different temporal connectives, which clearly guide the reader toward a specific temporal ordering of the situations described. For this reason, further studies are currently examining the role of lexically marked temporal and causal connectives in EP.

The present findings are also broadly consistent with the corpus-based patterns reported earlier. In particular, the processing advantage observed for the SubMain Result condition suggests that readers benefit from sentence configurations in which the linear order of the clauses is compatible with the chronological sequence of the eventualities, thereby facilitating the incremental establishment of the DR. This converges with Asr and Demberg's (2012) observation that speakers tend to organize discourse so that the textual order mirrors the temporal order of events whenever possible. At the same time, however, our results cannot directly address the (non-)existence of a general preference for reversing argument order, as discussed by Mendes et al. (2023) for Portuguese, since our study design did not allow for a direct comparison between the Explanation and Result conditions.

The precise interpretation of *wrap-up* effects, however, remains unclear. According to Noordman et al. (1992), when the relevant information is already part of the reader's knowledge, causal inferences are generated during reading, since both the concepts and their relations can be readily activated. When such knowledge is not readily available, however, integration may occur after the sentence has been read, during a later stage of post-reading processing. In this sense, the reader's knowledge plays a crucial role. It therefore remains possible that the wrap-up effects observed in our data in Narr condition reflect delayed inferential processing when a clear causal link is not immediately available.

Taken together, these findings provide support for both research questions addressed in the present study. Regarding RQ1, the results indicate that the linear order of clauses influences the online establishment of DRs, with SubMain configurations supporting an incremental processing that is different in the presence or absence of causality links. Regarding RQ2, the results suggest that intrinsic DRs (the causal conditions Result and Explanation) and extrinsic DRs (the temporal conditions Narration and Inverted Narration) are processed differently during online sentence comprehension. Overall, the causal conditions showed a processing advantage over the temporal conditions, although part of this effect may also reflect the temporal underspecification of *quando*, which requires readers to infer the temporal ordering of the eventualities without any further explicit cues in the narrative

conditions. Together, these findings indicate that both clause order and the semantic nature of the DR contribute to the interpretation of *quando*-clauses in European Portuguese.

6. Conclusions

This article presented a psycholinguistic study of DRs in EP, framed within a formal semantic perspective. As part of a broader research programme on the processing of DRs, the study sought to integrate insights from formal semantics and psycholinguistics by providing an updated theoretical overview of the topic and reporting experimental evidence from an online self-paced reading task.

The results indicate that discourse interpretation is guided by incremental and context-sensitive mechanisms that go beyond strictly compositional accounts of meaning. Based on the reviewed literature as well as on the results analyzed in this article, we conclude that the linear order of clauses interacts with the establishment of DRs, with SubMain configurations displaying a more incremental processing pattern and clear differences between the presence and absence of causality. DRs are thus established through the interaction of semantic, structural, and cognitive constraints during incremental processing.

By bringing together formal semantic analyses and psycholinguistic evidence, this study contributes to a better understanding of how DRs are established during real-time comprehension. Future work will extend this line of research by employing eye-tracking methodologies to investigate the time course of these processes in greater detail.

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References

- Asher, N., & Lascarides, A. (2003). *Logics of conversation*. Cambridge University Press.
- Asr, F. T., & Demberg, V. (2012). Implicitness of discourse relations. In M. Kay & C. Boitet (Eds.), *Proceedings of COLING 2012* (pp. 2669–2684). The COLING 2012 Organizing Committee. <https://aclanthology.org/C12-1163/>
- Cozijn, R., Noordman, L. G. M., & Vonk, W. (2011). Propositional integration and world-knowledge inference: Processes in understanding *because* sentences. *Discourse Processes*, 48(7), 475–500. <https://doi.org/10.1080/0163853X.2011.594421>
- Cunha, L. F. (2000). Valores temporais das orações com quando. *Cadernos de Linguística*, 8, 311–333.
- Cunha, L. F., & Silvano, P. (2009). O papel das restrições aspectuais nas relações retóricas: O caso das frases complexas com quando. In A. Fiéis & M. A. Coutinho (Eds.), *Textos Seleccionados. XXIV Encontro Nacional da Associação Portuguesa de Linguística* (pp. 239–250). Associação Portuguesa de Linguística.
- Das, D., & Egg, M. (2023). Testing the continuity hypothesis: A decompositional approach. In S. Carvalho, A. F. Khan, A. Ostroški Anić, B. Spahiu, J. Gracia, J. P. McCrae, D. Gromann, B. Heinisch, & A. Salgado (Eds.), *Proceedings of the 4th Conference on Language, Data and Knowledge* (pp. 449–454). NOVA CLUNL, Portugal. <https://aclanthology.org/2023.ldk-1.48/>

- Das, D., & Taboada, M. (2018). Signaling of coherence relations in discourse, beyond discourse markers. *Discourse Processes*, 55(8), 743–770. <https://doi.org/10.1080/0163853X.2017.1379327>
- Falé, I., Luegi, P., Gomes, J., & Mendes, A. (2024, October 23-25). Relações causais e confirmativas com de facto: processamento de relações discursivas explícitas e implícitas em Português Europeu [oral communication]. 40.º Encontro Nacional da Associação Portuguesa de Linguística, Ponta Delgada, Açores.
- Frazier, L., & Clifton, C. (2005). The syntax-discourse divide: Processing ellipsis. *Syntax (Oxford, England)*, 8(2), 121–174. <https://doi.org/10.1111/j.1467-9612.2005.00077.x>
- Gershman, S. J., & Ullman, T. D. (2023). Causal implicatures from correlational statements. *PloS one*, 18(5), e0286067. <https://doi.org/10.1371/journal.pone.0286067>
- Gomes, J. N., Silvano, P., Leal, A., & Magalhães, V. (2024, 23-25 October). O processamento das orações gerundivas periféricas: um estudo psicolinguístico [oral communication]. 40.º Encontro Nacional da Associação Portuguesa de Linguística, Ponta Delgada, Açores.
- Hartshorne, J. K. (2014). What is implicit causality? *Language, Cognition and Neuroscience*, 29(7), 804–824. <https://doi.org/10.1080/01690965.2013.796396>
- Hoek, J., Zufferey, S., Evers-Vermeul, J., & Sanders, T. J. M. (2017). Cognitive complexity and the linguistic marking of coherence relations: A parallel corpus study. *Journal of Pragmatics*, 121, 113–131. <https://doi.org/10.1016/j.pragma.2017.10.010>
- Kleijn, S., Pander Maat, H. L. W., & Sanders, T. J. M. (2019). Comprehension Effects of Connectives Across Texts, Readers, and Coherence Relations. *Discourse Processes*, 56(5–6), 447–464. <https://doi.org/10.1080/0163853X.2019.1605257>
- Lassiter, D., & Franke, M. (2024). The rationality of inferring causation from correlational language. *Proceedings of the Annual Meeting of the Cognitive Science Society*, 46. <https://escholarship.org/uc/item/9p29w77n>
- Levy, R., & Jaeger, T. F. (2007). Speakers optimize information density through syntactic reduction. In B. Schölkopf, J. Platt, & T. Hoffman (Eds.), *Advances in neural information processing systems 19: Proceedings of the Twentieth Annual Conference on Neural Information Processing Systems (NIPS 2006)* (pp. 849–856). MIT Press.
- Liang, X., Xiao, F., Wu, L., Chen, Q., Lei, Y., & Li, H. (2016). The temporal order of word presentation modulates the amplitudes of P2 and N400 during recognition of causal relations. *Frontiers in Psychology*, 7, 1890. <https://doi.org/10.3389/fpsyg.2016.01890>
- Lobo, M. (2013). Subordinação adverbial. In E. B. P. Raposo, M. F. B. do Nascimento, M. A. C. da Mota, L. Segura & A. Mendes (Orgs.), *Gramática do Português, volume II* (pp. 1981–2057). Fundação Calouste Gulbenkian.
- Magalhães, V., Gomes, J. N., & Silvano, P. (in press). Sobre o processamento psicolinguístico das relações discursivas em Português Europeu: Resultados de uma tarefa de self-paced reading. *Letrônica*, 19.
- Mann, W., & Thompson, S. (1988). Rhetorical Structure Theory: Toward a functional theory of text organization. *Text*, 8(3), 243–281.
- Marchal, M., Scholman, M. C. J., & Demberg, V. (2022). The effect of domain knowledge on discourse relation inferences: Relation marking and interpretation strategies. *Dialogue and Discourse*, 13(2), 49–78. <https://doi.org/10.5210/dad.2022.202>
- Mendes, A., Zeyrek, D., & Oleškevičienė, G. (2023). Explicitness and implicitness of discourse relations in a multilingual discourse bank. *Functions of Language*, 30(1), 67–91. <https://doi.org/10.1075/fol.22011.men>
- Moens, M., & Steedman, M. (1988). Temporal Ontology and temporal reference. *Computational Linguistics*, 14(2), 15–28.

- Móia, T., & Viotti, E. (2004). Sobre a semântica das orações gerundivas adverbiais. In I. Duarte & I. Leiria (Orgs.), *Actas do XX Encontro Nacional da Associação Portuguesa de Linguística* (pp. 715–729). Associação Portuguesa de Linguística.
- Münte, T. F., Schiltz, K., & Kutas, M. (1998). When temporal terms belie conceptual order. *Nature*, 395(6697), 71–73. <https://doi.org/10.1038/25731>
- Noordman, L. G., Vonk, W., & Kempff, H. J. (1992). Causal inferences during the reading of expository texts. *Journal of Memory and Language*, 31(5), 573–590. [https://doi.org/10.1016/0749-596X\(92\)90029-W](https://doi.org/10.1016/0749-596X(92)90029-W)
- Oliveira, F., Cunha, L. F., & Silvano, P. (2010). Relações retóricas em textos: A contribuição do aspecto. In *Estudos Linguísticos / Linguistic Studies* (Vol. 5, pp. 277–291). Edições Colibri / Centro de Linguística da Universidade de Lisboa (CLUNL).
- Politzer-Ahles, S., Xiang, M., & Almeida, D. (2017). "Before" and "after": Investigating the relationship between temporal connectives and chronological ordering using event-related potentials. *PloS ONE*, 12(4), e0175199. <https://doi.org/10.1371/journal.pone.0175199>
- Raposo, E. B. P. (2013). Orações copulativas e predicções secundárias. In E. B. P. Raposo, M. F. B. Nascimento, M. A. C. Mota, L. Segura & A. Mendes (Orgs.), *Gramática do português* (Vol. 2, pp. 1285–1358). Fundação Calouste Gulbenkian.
- Sanders, T. (2005). Coherence, causality and cognitive complexity in discourse. In N. Aurnague, M. Bras, A. Le Draoulec & L. Vieu (Eds.), *Proceedings of the First International Symposium on the Exploration and Modelling of Meaning (SEM'05)* (pp. 105–114). Université de Toulouse II-le-Mirail.
- Sanders, T., Spooren, W., & Noordman, L. (1992). Toward a taxonomy of coherence relations. *Discourse Processes*, 15(1), 1–35.
- Segal, E. M., Duchan, J. F., & Scott, P. J. (1991). The role of interclausal connectives in narrative structuring: Evidence from adults' interpretations of simple stories. *Discourse Processes*, 14(1), 27–54. <https://doi.org/10.1080/01638539109544773>
- Scholman, M., Marchal, M., & Demberg, V. (2024). Connective comprehension in adults: The influence of lexical transparency, frequency, and individual differences. *Discourse Processes*, 61(8), 381–403. <https://doi.org/10.1080/0163853X.2024.2325262>
- Silvano, P. (2007). Semantic analysis of temporal when-clauses in European Portuguese. In *Actas da Conferência Internacional Linguística 2007*. Instituto de Literatura y Lingüística José Antonio Portuondo Valdor.
- Silvano, P. (2010). *Temporal and rhetorical relations: The semantics of sentences with adverbial subordination in European Portuguese* [Doctoral dissertation, Faculdade de Letras da Universidade do Porto]. Repositório Aberto da Universidade do Porto. <http://hdl.handle.net/10216/56024>
- Silvano, P. (2012). The rhetorical relations in complex sentences with quando ('when') in European Portuguese. *Belgian Journal of Linguistics*, 26(1), 65–83. <https://doi.org/10.1075/bjl.26.03sil>
- Silvano, P. (2013). A semântica das frases com subordinação adverbial: O contributo das relações retóricas. In F. Silva, I. Falé, I. Pereira & J. Veloso (Orgs.), *Textos Selecionados do XXVIII Encontro Nacional da Associação Portuguesa de Linguística* (pp. 595–614). Associação Portuguesa de Linguística.
- Silvano, P., Leal, A., Cordeiro, J., & Pais, S. (2023). DRIPPS: A corpus with discourse relations in perfect participial sentences. In S. Carvalho, A. F. Khan, A. O. Anić, B. Spahiu, J. Garcia, J. P. McCrae, D. Gromann, B. Heinisch & A. Salgado (Eds.), *Proceedings of the 4th Conference on Language, Data and Knowledge* (pp. 470–481). NOVA CLUNL. <https://aclanthology.org/2023.ldk-1.51/>
- Silvano, P., Leal, A., Ogródniczuk, M., Tomaszewska, A., Gomes, J., Cunha, L. F., Amorim, E., Lewandowska, M., Śliwicka, A., & Jorge, A. (2026). Fables-DTR: A corpus of fables annotated for discourse and temporal

- relations. In *Proceedings of the Fifteenth Language Resources and Evaluation Conference (LREC 2026)* (pp. 1856–1868). European Language Resources Association (ELRA). <https://doi.org/10.63317/5buggd55dy3e>
- Tecwyn, E. C., Bechlivanidis, C., Lagnado, D. A., Hoerl, C., Lorimer, S., Blakey, E., McCormack, T., & Buehner, M. J. (2020). Causality influences children’s and adults’ experience of temporal order. *Developmental Psychology*, 56(4), 739–755. <https://doi.org/10.1037/dev0000889>
- Tomaszewska, A., Silvano, P., Leal, A., & Amorim, E. (2024). ISO 24617-8 applied: Insights from multilingual discourse relations annotation in English, Polish, and Portuguese. In H. Bunt, N. Ide, K. Lee, V. Petukhova, J. Pustejovsky & L. Romary (Eds.), *Proceedings of the 20th Joint ACL - ISO Workshop on Interoperable Semantic Annotation @ LREC-COLING 2024* (pp. 99–110). ELRA and ICCL. <https://aclanthology.org/2024.isa-1.13/>
- Traxler, M. J., Sanford, A. J., Aked, J. P., & Moxey, L. M. (1997). Processing causal and diagnostic statements in discourse. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 23(1), 88–101. <https://doi.org/10.1037/0278-7393.23.1.88>
- Van den Broek, P. (1994). Comprehension and memory for narrative texts: Inferences and coherence. In M. A. Gernsbacher (Ed.), *Handbook of psycholinguistics* (pp. 539–588). Academic Press.
- Wei, Y., & Knoeferle, P. (2023). Causal inference: Relating language to event representations and events in the world. *Frontiers in Psychology*, 14, 1172928. <https://doi.org/10.3389/fpsyg.2023.1172928>
- Wilke, H., & Hoek, J. (2024). At-issueness and the Right Frontier: An investigation of Dutch. *Proceedings of the Annual Meeting of the Cognitive Science Society*, 46. <https://escholarship.org/uc/item/51n8z181>
- Zeyrek, D., Valūnaitė Oleškevičienė, G., & Mendes, A. (2024). *Multiple discourse relations in English TED Talks and their translation into Lithuanian, Portuguese and Turkish*. In P. Zweigenbaum, R. Rapp, & S. Sharoff (Eds.), *Proceedings of the 17th Workshop on Building and Using Comparable Corpora (BUCC) @ LREC-COLING 2024* (pp. 125–134). ELRA & ICCL. <https://aclanthology.org/2024.bucc-1.14/>
- Zufferey, S., & Degand, L. (2024). *Connectives and discourse relations*. Cambridge University Press.
- Zehr, J., & Schwarz, F. (2018). *PennController for Internet Based Experiments (IBEX)*. <https://doi.org/10.17605/OSF.IO/MD832>