

Event coreference and discourse relations

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Abstract

Event coreference is largely ignored in works on coreference as well as in works on temporal order in discourses, in which temporal relations between two eventualities e_1 and e_2 always suppose that $e_1 \neq e_2$. However, event coreference is not an uncommon phenomenon. We show that it is the keystone on which at least four types of discourses are based: on the one hand, particularizing and generalizing discourses, which can be viewed as special cases of elaboration and reformulation discourses respectively, on the other hand causal discourses in which the effect is expressed by means of a causative verb, which are generally analyzed as explanation or result discourses. Descriptions and linguistic analyses of these discourses allow us to present unusual linguistic phenomena (e.g., coreference between existentially quantified elements, or asymmetrical behavior of explanation or result discourses). The discourse relations involved are examined. This leads us to introduce and define new discourse relations. It also sheds a new light on the discourse relations Explanation and Result.

1 Introduction

Works on temporal relations between two eventualities e_1 and e_2 examine almost exclusively if one eventuality precedes, includes or overlaps with the other one [MS88, Ash93, Pus95]. All these temporal relations suppose that $e_1 \neq e_2$. We will concentrate on cases where $e_1 = e_2$, i.e., on *event coreference*. Event coreference can be seen as a particular case of either event elaboration or event reformulation, for which it has been acknowledged that time is not understood as moving [SC91].

Contrary to coreference between objects, coreference between events has hardly been studied in detail, except for a (pro)nominal phrase referring to an event as in (1) in which the pronoun *this* refers to the event described in the first sentence, see among others [Web88, Ash93].

- (1) Ted arrived late. This irritated Mary.

Nevertheless, there is a number of other cases of event coreference since *the description of an event e can be of three types*: it is either a sentence, or a (pro)nominal phrase or an abstraction which is not linguistically realized. This last case occurs when e is a sub-event of a complex event (cf. *infra*). Between two successive descriptions D_1 and D_2 of the same event e , there exist therefore $3^2 = 9$ cases of event coreference potentially observable depending on the types of D_1 and D_2 . In this paper, the following cases are examined:

- In Section 2, event coreference when D_1 and D_2 are both sentences (noted as S_i) as in (2a) and (2b) is examined.

- (2) a. The yugu team won a victory. They beat the tara team yesterday.
- b. The yugu team beat the tara team yesterday. Therefore, they won a victory.

In (2a), the two sentences refer to the same event, with more information on that event in the second sentence (which "particularizes" the first one). In (2b), obtained from (2a) by reversing the order of the sentences, S_2 "generalizes" S_1 .

- In Section 3, event coreference when D_i ($i = 1, 2$) is a sentence and D_j ($j = 1, 2, j \neq i$) is not syntactically realized is examined. More precisely, *causal discourses* in which the effect is expressed by means

of a causative verb (e.g., *crack*) are examined, as in (3a) and (3b) ((3b) is obtained from (3a) by reversing the order of the sentences).

- (3) a. Ted cracked the carafe. He hit it against the sink.
- b. Ted hit the carafe against the sink. He cracked it.

The causing sub-event of the complex event described by *crack* is not linguistically realized, it is just known that it is an act by Ted on the carafe. However, it is understood as coreferent to the event described in the cause sentence (*Ted hit the carafe against the sink*).

Studying event coreference requires the definition of *two types of coreference relation according to the quantity of information conveyed*:

*Two successive descriptions D_1 and D_2 of the same entity x (event or object) are in a **particularization** relation noted as $D_2 = \text{PART}(D_1)$ iff D_2 conveys some new information about x when compared to the information known from D_1 .*

*Two successive descriptions D_1 and D_2 of the same entity x (event or object) are in a **generalization** relation noted as $D_2 = \text{GEN}(D_1)$ iff D_2 does not bring any new information about x (and $D_1 \neq D_2$).*

Let us illustrate these two types of coreference with the well-known case where x is an object. D_1 and D_2 are then (pro)nominal phrases. In (4a), the demonstrative NP *this New Yorker girl* = $\text{PART}(\text{an actress})$ since it brings new information (*the actress is a New Yorker girl*). In (4b), the pronoun *she* = $\text{GEN}(\text{an actress})$: a pronoun cannot bring any new information. Finally, in (4c) the definite or demonstrative NP *the / this artist* = $\text{GEN}(\text{an actress})$ since *artist*, hyperonym of *actress*, does not bring new information.

- (4) a. Ted had a drink with an actress. This New Yorker girl irritates Mary.
- b. Ted had a drink with an actress. She irritates Mary.
- c. Ted had a drink with an actress. The / This artist irritates Mary.

These two types of coreference relation according to the quantity of information conveyed do not play a major role in the literature on object coreference. However, they are essential for event coreference. In the next sections, it will be shown that (2a) and (3a) involve an event coreference relation of type particularization, (2b) and (3b) an event coreference relation of type generalization. This difference in the type of coreference explains asymmetrical data. For example, it will be shown that any kind of adjunct can be inserted in the first sentence of (2a) or (3a), while the insertion of

adjuncts in the first sentence of (2b) or (3b) is limited. As a consequence, the causal discourses in (3a) and (3b) are not really converse, despite what is generally believed. More generally, it will be shown that particularization and generalization are not symmetrical: the inverse of a generalization relation is a particularization relation, but the inverse of a particularization relation is not always a generalization relation.

We will show that it is necessary to lay down *new discourse relations* (the name of a discourse relation starts with a capital letter): Particularization (a particular case of Elaboration) for (2a) and Generalization (a particular case of Reformulation) for (2b). Of course, these new discourse relations are closely related to the types of event coreference: particularization (abbreviated as PART) for (2a) and generalization (abbreviated as GEN) for (2b). Moreover, we will show that these discourse relations are involved in causal discourses: Particularization for (3a) and Generalization for (3b). We will question the analysis of (3a) with Explanation and that of (3b) with Result, and shed a new light on these causal discourse relations. Discourse relations will be studied in the formal framework of SDRT (Segmented Discourse Representation Theory, [Ash93, AL95, AP00, ?]¹).

2 Event coreference between two sentences

Sections 2.1 and 2.2 provide linguistic descriptions, which are formalized in Section 2.3. Section 2.4 examines the discourse relations involved.

Notation: The symbol X_i^r with $i = 1$ or 2 denotes the predicate or an argument or modifier in S_i with the role r ; for an argument $r = \text{agent, patient, ...}$; for a modifier $r = \text{time, location, ...}$; for the predicate, r is irrelevant.

2.1 Particularizing discourses

A particularization event coreference relation as defined above is to be found in “particularizing discourses” (henceforth PDs) such as (2a) or (5).

(5) Fred damaged a garment. He stained a shirt.

In (5), the same event is described in both sentences, with more information in S_2 . S_2 particularizes S_1 since its predicate is a hyponym of the predicate

¹We assume that the reader knows SDRT. If it is not the case, she can skip the SDRT formalizations presented here.

in S_1 (*stain* < *damage*) and the (indefinite) object is a hyponym of the (indefinite) object in S_1 (*shirt* < *garment*), while its subject is a (pronominal) anaphora of the subject in S_1 ².

More natural examples of PDs are observed when extralinguistic knowledge is at stake, as in (6). These PDs are based on an extension of hyperonymy, namely X *compliment* Y > X *tell* Y *that* Y *is pretty* in (6a), and X *be sick* > X *have the flu* in (6b). These extended hyperonymy relations rely on cultural or encyclopedic knowledge.

- (6) a. Fred complimented Sue. He told her that she is pretty.
b. Fred is sick. He has the flu.

Our linguistic study is not corpus based. Nevertheless it is easy to find real examples of PDs, such as (7a) found in [Ash93, p. 1].

- (7) a. (...) linguist and philosophers (...) developed a sophisticated understanding of events and states and the expressions that denote them. They developed a typology of such entities.

The particularization interpretation of a PD can be explicitly marked, as in (8) with the cue phrase *more precisely*.

- (8) Fred damaged a garment. More precisely, he stained a shirt.

The PD in (5) or (8) gives rise to an unusual phenomenon: the two indefinite NPs *a garment* and *a shirt* are coreferent. This is unusual since it is generally admitted [KR93, Cor95] that an indefinite NP has an existential reading (i.e. introduces a new discourse referent) and that therefore two indefinite NPs are not coreferent³. This is the case in (9) in which two garments are involved, whereas only one garment is involved in (5). We will see in Section 2.4 how to compute the coreference of two indefinite NPs in PDs.

- (9) Fred stained a garment. Joe tore a shirt.

²The two sentences are in the same tense, which is required for event coreference.

³A few cases exist in which two indefinite NPs are coreferent, (ia) and (ib) taken from [Cor94].

- (i) a. A man arrived. He was a New Yorker.
b. A man, a New Yorker, arrived.

However, the examples presented here with two coreferent indefinite NPs have not been described in the literature, as far as we know.

A discourse such as (5) in which at least one element in S_2 specifies a corresponding element in S_1 is called a “PD by specification”. Another type of PD is given in (10). In (10), the modifier *during dinner* in S_2 provides temporal information about e ; the other elements X_2^r in S_2 anaphorize or repeat the corresponding elements X_1^r in S_1 .

(10) Fred stained a shirt. He stained it during dinner.

A discourse such as (10) in which at least one element X_2^r in S_2 has no corresponding element X_1^r in S_1 is called a “PD by adjunction”. Specification and adjunction may be combined in a single PD. In (11), *a shirt* specifies *a garment* and the time adjunct in S_2 has no corresponding element in S_1 .

(11) Fred stained a garment. He stained a shirt during dinner.

At face value, one gets a PD when each element X_2^r in S_2 is either an (extended) hyponym, an anaphora or a repetition of a corresponding element X_1^r in S_1 or has no corresponding element X_1^r in S_1 .

To summarise, in text understanding, it has to be computed that there is only one garment and one event involved in (5)⁴. In text generation, it must be determined under which conditions a PD may be uttered and which linguistic forms should be produced [Rou00].

2.2 Generalizing restatement discourses

A generalization event coreference relation as defined in Section 1 is to be found in “generalizing restatement discourses” (henceforth GDs) such as (12).

- (12) a. Fred stained a shirt. Therefore, he damaged a garment.
b. Fred murdered Sue. Therefore, he committed a crime.

While a PD stands mainly at the informational level, a GD stands mainly at the intentional level: the first sentence in (12a) or (12b) describes what the speaker wants the hearer to know about an event e , the second one consists in her restatement of e . By definition, a restatement cannot bring new information, but it can present an event in a new light, for example, if the speaker has the intention to forge links with other data, (13).

- (13) Fred murdered Sue. Therefore, he committed a crime for which he risks the death sentence.

⁴See also [HGA97] for event coreference issues within an information extraction system.

(12a) is created from (5) by reversing the order of the sentences (and the anaphoric relations), and by introducing a cue phrase like *therefore*, with an epistemic value [RJ96]. S_2 generalizes S_1 because *damage* and *garment* are respectively hyperonyms of the corresponding elements in S_1 . In (12b), S_2 generalizes S_1 because the complex predicate *commit a crime* is a hyperonym of *murder*.

As for PDs, more natural examples of GDs are observed when an extended notion of hyperonymy is at stake, (14).

- (14) a. Fred told Mary that she is pretty. Therefore, he complimented her.
 b. Fred has the flu. Therefore, he is sick.

At face value, one gets a GD when each element X_2^i in S_2 is an (extended) hyperonym, an anaphora or a repetition of a corresponding element X_1^i in S_1 .

2.3 Formalized conditions

In [Dan01], the conditions to observe a PD or GD have been formalized in the framework of SDRT, using a notion of implication between two DRSs. Intuitively, in first approximation, in a PD, S_2 “implies” S_1 . Informally, staining a shirt “implies” damaging a garment, so *Fred stained a shirt* “implies” *Fred damaged a garment* in (5). At the opposite, in a GD, S_1 “implies” S_2 .

Nevertheless, the situation is more complex: it is indeed the case that S_1 always “implies” S_2 in a GD. However, it is not always the case that S_2 “implies” S_1 in a PD. There is an asymmetry between PDs and GDs. More precisely, if S_1 . (*therefore*) S_2 . is a GD, then S_2 . S_1 . is a PD. But the converse does not hold, as illustrated in (15). (15a) is a PD. S_1 in (15a) includes a time adjunct (*during dinner*) which is not repeated in S_2 , although it is understood that the staining event occurred during dinner and that it is the same event as the damaging event. This means that the second sentence of a PD has to bring new information but has not to repeat all the information conveyed in the first sentence. On the other hand, the second sentence of a GD cannot bring new information at all. (15b), is incoherent (hence the sign #) and cannot be interpreted as a GD.

- (15) a. Ted damaged a garment during dinner. He stained a shirt.
 b. # Ted stained a shirt. Therefore, he damaged a garment during dinner.

Another type of PD examples with no corresponding GD is illustrated in (16a): (16a) is a PD although the verb in S_2 is an *hyperonym* of the verb in S_1 . It has no corresponding GD - (16b) is not a GD. (16a) is paraphrased by (16c) with the anaphoric form *do it*.

- (16) a. Ted stained a shirt. He damaged the garment during dinner.
 b. # Ted damaged a shirt during dinner. Therefore, he stained it.
 c. Ted stained a shirt. He did it during dinner.

To put it in a nutshell, the conditions to observe a GD (noted \mathcal{C}_{GD}) are based on a notion of implication between the DRSs which represent the sentences, while the conditions to observe a PD (noted \mathcal{C}_{PD}) are slightly more complex.

2.4 Discourse relations

It is likely that anyone working on discourse relations would lay down that the discourse relation between the two sentences of a PD is Elaboration. However, we are going to show that it is necessary to postulate the existence of a new discourse relation called "Particularization" which implies an event coreference. Beforehand, a terminological remark: "particularization" (abbreviated as PART) designates a type of coreference as defined in section 1; "Particularization" designates a discourse relation between two sentences. These two notions are linked in SDRT in the following way: if π_i is the label for the DRS K_i representing the sentence S_i , then $K_2 = \text{PART}(K_1) \Leftrightarrow \text{Particularization}(\pi_1, \pi_2)$.

Elaboration is given various definitions [Hob79, MT88, AL95], but whatever its definition, this discourse relation implies no event coreference relation. Let us illustrate this point with a "classic" example of Elaboration, (17a) or its shorter version, (17b). The first sentence denotes an event e_1 which is "elaborated" in the next sentence(s) which bring(s) new information on **one** or **some** stages (sub-events) of e_1 . No event coreference is at stake: a trip by plane cannot not be reduced to a takeoff and a landing and even less to a simple takeoff. There exists a number of stages in the trip which are described neither in (17a) nor in (17b).

- (17) a. Nicholas flew from Austin to Paris. He took off at 6 am. He landed at 2 pm.
 b. Nicholas flew from Austin to Paris. He took off at 6 am.

Therefore it is necessary to postulate the existence of a discourse relation (Particularization) which implies an event coreference relation⁵. Only this discourse relation allows us to preserve well established insights on discourse referents. The argumentation is the following: examples such as (5) are productive counter-examples to the principle of the existential reading of an indefinite NP (which entails that two indefinite NPs are not coreferent). Hence, two solutions towards this principle are available:

- Given these productive counter-examples, this principle is abandoned and an anaphoric reading of indefinite NPs is proposed to allow the coreference of two indefinite NPs. This solution does not seem sound since this principle is nearly always true, except in PDs (and in GDs and in some well known exceptions, see note 2).
- This principle is not abandoned. The two indefinite NPs in (5) are represented in the standard way: two discourse referents x and y with the complete conditions $\text{garment}(x)$ and $\text{shirt}(y)$ are introduced. Yet the coreference relation $x = y$ is established thanks to the discourse relation Particularization. This discourse relation implies an event coreference relation which implies in turn that the arguments with the same role are coreferent. In other words, it is because the discourse relation Particularization is established between the two sentences of (5) that it is known that the two sentences refer to the same event, and therefore that the two patients *a garment* and *a shirt* are coreferent, i.e., $x = y$.

This last solution seems better. It raises the following question: how can it be established that the discourse relation in (5) is Particularization (which amounts to establishing that (5) is a PD)? The answer to this question lies in linguistic knowledge: the two sentences in a PD follow some strong linguistic constraints which have been described in Sections 2.1 and 2.3. This set of constraints, noted as \mathcal{C}_{PD} , allows the computation of the discourse relation Particularization. In SDRT, the rule is the following (where $>$ is the symbol for the default implication): $(\tau, \pi_1, \pi_2) \wedge \mathcal{C}_{PD} > \text{Particularization}(\pi_1, \pi_2)$.

Summary on event coreference between two sentences

It is necessary to postulate the existence of a new discourse relation, Particularization, which implies an event coreference relation between the

⁵In the framework of SDRT, the indefeasible consequence of Particularization is written in the following way: $\text{Particularization}(\pi_1, \pi_2) \rightarrow \text{Main-event}(\pi_1) = \text{Main-event}(\pi_2)$.

event e_1 and e_2 described in the first and second sentences. It allows the establishment of an event coreference relation although the events involved are existentially quantified. This event coreference relation implies the coreference of participants with the same thematic role, even if they are existentially quantified. This discourse relation differs from Elaboration for which only one or some stages (sub-events) of e_1 are specified. Nevertheless, Particularization can be seen as a particular case of Elaboration. For exactly the same reason, a discourse relation Generalization has to be laid down in order to establish the event co-reference in such examples as (12).

3 Causal discourses

3.1 Linguistic description

Examples (3a) et (3b), repeated in (18a) and (18b), express a "direct causation" [Fod70, Sch75]. It is generally admitted that the discourse relation is Explanation in (18a) and Result in (18b). We adopt this position in this section before questioning it in the next section.

- (18) a. Ted cracked the carafe. He hit it against the sink.
 b. Ted hit the carafe against the sink. He cracked it.

In these causal discourses, the effect is expressed by means of a causative verb, here *crack*. It is well known (see among other [MS88, Pus91, Pus95]) that a causative verb denotes a complex event which can be broken down into:

- a causing sub-event, here a non specified⁶ act by Ted on the carafe which is represented in the simplified⁷ DRS π_1 : $\boxed{e_1 - ?ACT(t, c)}$,
- and a resulting state, here the cracked state of the carafe which is represented by π_2 : $\boxed{e_2 - cracked(c)}$.

π_1 and π_2 are grouped in the DRS π_3 , which is noted as $\pi_3 = (\pi_1, \pi_2)$. π_3 can be viewed as the DRS representing the sentence with the causative verb (*Ted cracked the carafe.*). The analysis of a clause with a causative verb is sketched in Figure 1.

⁶The act by Ted on the carafe is not specified, however it is understood as an act which affects its patient, i.e., the carafe.

⁷Our simplified graphic representation of DRS includes conditions (in a compact way) but not the universe. We leave it to the reader to re-establish the complete DRSs.

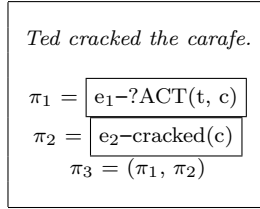


Figure 1: Analysis of a clause with a causative verb

The causal interpretation of discourses such as (18a) or (18b) can be explained in linguistic terms thanks to the notion of event coreference.

The cause sentence denotes an event which is interpreted as coreferent to the causing sub-event of the complex event referred to by the causative verb.

For example, in (18a) or (18b), the hitting event is coreferent to the causing sub-event of *crack*, i.e. the non specified act by Ted on the carafe. Let us underline that the causal interpretation of the discourses we are concerned with is totally bound to event coreference. To emphasize this point, consider the discourses in (19). Normally they should not be given a causal interpretation. However, if the hearer imagines that Ted is James Bond equipped with a special camera, then she may assume a causal interpretation of (19). In such a case, she assumes an event coreference between the *taking a photo* event⁸ and the causing sub-event of *crack*.

- (19) a. Ted cracked the carafe. He took a photo of it.
 b. Ted took a photo of the carafe. He cracked it.

The analysis of (18a) is schematized in Figure 2 with the event coreference relation $e_1 = e_4$, where e_4 is the hitting event. π_1 introduces an underspecified predicate *?-ACT*. This predicate is specified coreferentially in π_4 which labels K_4 , the DRS for the hitting sentence. *hit* can be considered as an hyponym of *?-ACT*. The event coreference relation $e_1 = e_4$ is therefore of type particularization, i.e. $K_4 = PART(K_1)$, since K_4 brings new information as compared to K_1 . Thus, Particularization (π_1, π_4) can be laid down.

⁸The taking a photo event is then understood as an act which affects its patient, see note 6.

<p><i>Ted cracked the carafe. He hit it against the sink.</i></p> $\pi_1 = \boxed{e_1-?ACT(t, c)}$ $\pi_2 = \boxed{e_2-cracked(c)}$ $\pi_3 = (\pi_1, \pi_2)$ $\pi_4 = \boxed{e_4-hit(t, c, s)}$ <p>$K_4 = PART(K_1) \Leftrightarrow \text{Particularization}(\pi_1, \pi_4)$ with $e_1 = e_4$</p>	<p><i>Ted hit the carafe against the sink. He cracked it.</i></p> $\pi_5 = \boxed{e_5-hit(t, c, s)}$ $\pi_6 = \boxed{e_6-?ACT(t, c)}$ $\pi_7 = \boxed{e_7-cracked(c)}$ $\pi_8 = (\pi_6, \pi_7)$ <p>$K_6 = GEN(K_5) \Leftrightarrow \text{Generalization}(\pi_5, \pi_6)$ with $e_5 = e_6$</p>
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Fig.2 : Analysis of (18a) (preliminary version)

Fig.3 : Analysis of (18b) (preliminary version)

The analysis of (18b), similar to that of (18a), is schematized in Figure 3 with the event coreference relation $e_5 = e_6$ ⁹. This coreference relation is of type generalization, i.e. $\pi_6 = GEN(\pi_5)$, since K_6 does not bring new information compared to K_5 . K_6 can be viewed as an anaphora by hyperonymy of K_5 .

The undebatable link between causal interpretation and event coreference is shared by both Explanation and Result discourses. However these discourses differ in that Explanation discourses rely on an event coreference of type particularization, whereas Result discourses rely on a generalization event coreference. In parallel with the fact that some PDs do not have a corresponding GD (Section 2.3), some Explanation discourses do not have a corresponding Result discourse. Let us illustrate this point with the adjunction of modifiers in the sentence with a causative verb¹⁰. Two types of adjuncts must be distinguished:

- those with scope over the causing sub-event, for example, temporal adverbs (*during dinner*). In *Ted cracked the carafe during dinner*, *during dinner* has scope over the the causing sub-event. The information known on this event is: $e_1-?ACT(t, c) \wedge \text{during-dinner}(e_1)$.
- those without scope over the causing sub-event, for example “quantifier” adverbs (*badly*). In *Ted cracked the carafe badly*, *badly* has scope over the resulting state but not over the causing sub-event. The information on the causing sub-event is $e_1-?ACT(t, c)$, and that on the resulting state is $e_2-cracked(c) \wedge \text{badly}(e_2)$.

⁹The numbering $\pi_5-\pi_8$ is used instead of the standard one $\pi_1-\pi_4$ to refer later to the DRSs in figures 1 and 2 without ambiguity.

¹⁰The claim that Explanation discourses rely on an event coreference of type particularization, whereas Result discourses rely on a generalization event coreference is thoroughly justified in [Dan00].

The adjunction (in the sentence with a causative verb) of a modifier with scope over the causing sub-event, e.g., temporal adverb, does not alter the causal interpretation when Explanation is involved, see (20a) with the adjunction of *during dinner* in the *crack* sentence. But it does alter it when Result is involved, see (20b) which is marked with the sign # to indicate that no causal interpretation is at stake¹¹. This asymmetry can be explained by a principle on the type of the event coreference relation: it has to be of type particularization for Explanation, as it is in (20a), see (21a) which resumes the information known from (20a). It has to be of type generalization for Result, which is not the case in (20b), see (21b), which resumes the information known from (20b) and where the generalization coreference relation is negated, which goes along with the fact that (20b) has no causal interpretation.

- (20) a. Ted cracked the carafe during dinner. He hit it against the sink.
 b. # Ted hit the carafe against the sink. He cracked it during dinner.

- (21) a. $e_4\text{-hit}(t, c, s) = \text{PART}(e_1\text{-?ACT}(t, c) \wedge \text{during-dinner}(e_1))$ with $e_1=e_4$
 b. $\neg[e_6\text{-?ACT}(t, c) \wedge \text{during-dinner}(e_6) = \text{GEN}(e_5\text{-hit}(t, c, s))]$ with $e_5=e_6$

On the other hand, the adjunction of a of a modifier without scope over the causing sub-event, e.g., “quantifier” adverb, is possible in both Explanation and Result discourses while maintaining a causal interpretation, (22). This goes along with the fact that the coreference relation is of type particularization in (22a), see (23a), and of type generalization in (22b), see (23b).

- (22) a. Ted cracked the carafe badly. He hit it against the sink.
 b. Ted hit the carafe against the sink. He cracked it badly.

- (23) a. $e_4\text{-hit}(t, c, s) = \text{PART}(e_1\text{-?ACT}(t, c))$ with $e_1=e_4$
 b. $e_6\text{-?ACT}(t, c) = \text{GEN}(e_5\text{-hit}(t, c, s))$ with $e_5=e_6$

Let us move to psychological causative verbs (e.g. *irritate*) whose subject can refer to an event (*This incident irritated Mary*) contrarily to causative verbs which denote a physical change of state (**This incident cracked the carafe*). Two types of discourses are thus available to express Result when

¹¹As shown by the fact that it is impossible to insert a causal connective such as *therefore* between the two sentences.

the change of state is psychological, as illustrated in (24): the subject of *irritate* refers to the cause in (24a) and to the agent of the cause in (24b). Our analysis puts forward that these two discourses, which describe the same situation but differs in communicative structure, involve both an event coreference relation. This coreference relation is "classic" in (24a) : (pro)nominal NP referring to an event. In (24b), it holds between the event referred to in the cause sentence and the causing sub-event of the causative verb. It can be considered that (24b) involves a metonymy: *he* is used instead of *his act*. With a psychological verb, Result can therefore be expressed by the metonymic or full form. With a causative non-psychological verb, only the metonymic form is available.

- (24) a. Ted hit the carafe against the sink. This / This incident irritated Mary.
 b. Ted hit the carafe against the sink. He irritated Mary.

3.2 Discourse relations

We are going to shed a new light on Explanation and Result. It is common knowledge to state that these discourse relations apply when a causal relation is involved, and when, for Explanation, the description of the effect precedes that of the cause, while for Result, the inverse discursive linear order is observed. These discourse relations can thus be established only when the following axioms (necessary conditions) are verified¹²:

A1 : Explanation and Result hold between two DRSs, one representing the cause, the other one the effect.

A2 : It is possible to associate with these two DRSs two distinct syntactic realizations (which are thus linearly ordered); if the syntactic realization associated with the effect DRS precedes that associated with the cause DRS, Explanation applies; with the inverse discursive order, Result applies.

We are going to show that two opposite discourse theories, RST (Rhetorical Structure Theory, [MT88]) and SDRT in its [AP00]) version (noted as

¹²These axioms are written in SDRT style, however they do not constitute SDRT rules to infer Explanation or Result. More generally, in this section, the issue is to determine which discourse relations should be established in discourses such as (18a) or (18b). The issue is not to compute these discourse relations.

SDRT-00), lay down Explanation or Result in such ways that A1 is not verified for RST while A2 is not verified for SDRT-00. Next we will propose a solution such that both A1 and A2 are verified.

In RST, discourse relations hold only between two sentences or two clauses (or between two DRSs representing sentences or clauses in the SDRT framework). As a consequence, it is said that Explanation holds between the two sentences of (18a) and Result between the two sentences of (18b). This amounts to Explanation (π_3, π_4) and Result (π_5, π_8) in the DRSs of figures 1 and 2. However this analysis is inappropriate: the sentence with the causative verb refers *both* to the cause (it indicates who is the agent) and to the effect. Axiom A1 is thus not verified.

Contrarily to RST, in SDRT-00, discourse relations hold between two DRSs without any constraint on their possible syntactic realizations. Therefore, Asher and Pustejovsky can propose to record in the lexical entry of a causative verb that the DRSs for the causing sub-event and the resulting state are linked by Result. This amounts to Result (π_1, π_2) and Result (π_6, π_7) in our examples. However, there is no criterion to choose Result rather than Explanation: the DRSs of the two sub-events involved are only abstract representations without corresponding syntactic realizations. Axiom A2 is thus not verified. The choice of Result rather than Explanation can be explained by the fact that Asher and Pustejovsky chose the discourse relation which follows the chronological order of the events (the cause precedes the effect). However, it is necessary to maintain a distinction between discursive and temporal orders. Recall that the discourses (18a) and (18b), with the same temporal order and different discursive orders, are based either on a particularization or generalization event coreference, which implies asymmetrical behavior, e.g., for the insertion of adjuncts.

It is thus not justified to link by Result the DRSs for the causing sub-event and the resulting state of a causative verb. On the other hand, we propose to link these two DRSs by means of the events they represent: we propose a conceptual (non discursive) link, noted as CAUSE, between the events involved, e.g. CAUSE(e_1, e_2) and CAUSE(e_6, e_7) in our examples. This link can be recorded in the lexical entry of a causative verb.

We propose moreover to lay down that the DRSs for the cause sentence and the resulting state are linked by Explanation or Result, e.g. Explanation (π_2, π_4) and Result (π_5, π_7) in our examples. Let us show that both axioms A1 and A2 are verified with this solution; the argumentation will be presented only for Explanation (π_2, π_4) , since that for Result (π_5, π_7) is entirely similar.

<p style="text-align: center;"><i>Ted cracked the carafe. He hit it against the sink.</i></p> $\pi_1 = \boxed{e_1\text{-?ACT}(t, c)}$ $\pi_2 = \boxed{e_2\text{-cracked}(c)}$ $\pi_3 = (\pi_1, \pi_2) \text{ with CAUSE}(e_1, e_2)$ $\pi_4 = \boxed{e_4\text{-hit}(t, c, s)}$ <p style="text-align: center;">Particularization(π_1, π_4) $\rightarrow e_1 = e_4$ Explanation(π_2, π_4)</p>	<p style="text-align: center;"><i>Ted hit the carafe against the sink. He cracked it.</i></p> $\pi_5 = \boxed{e_5\text{-hit}(t, c, s)}$ $\pi_6 = \boxed{e_6\text{-?ACT}(t, c)}$ $\pi_7 = \boxed{e_7\text{-cracked}(c)}$ $\pi_8 = (\pi_6, \pi_7) \text{ with CAUSE}(e_6, e_7)$ <p style="text-align: center;">Generalization(π_5, π_6) $\rightarrow e_5 = e_6$ Result(π_5, π_7)</p>
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Fig.4 : Analysis of (18a)

Fig.5 : Analysis of (18b)

- For the axiom A1 in Explanation (π_2, π_4), it has to be verified that π_4 represents the cause, and π_2 the effect. This is the case: these DRSs describe the events e_4 and e_2 which are linked by the conceptual link CAUSE thanks to the following implication: $\text{CAUSE}(e_1, e_2) \wedge e_1 = e_4 \Rightarrow \text{CAUSE}(e_4, e_2)$.

Note that a formal basis for A1 can be given, see A1'.

A1' : Explanation and Result hold between two DRSs which describe two events linked by CAUSE.

- For the axiom A2 in Explanation (π_2, π_4), it has to be verified that the syntactic realization associated with the effect DRS, i.e., π_2 , precedes that associated with the cause DRS, i.e., π_4 . This is the case: π_2 has no syntactic realization, however, π_2 is an element of π_3 which does have a syntactic realization, namely the sentence with the causative verb. This sentence precedes the syntactic realization of π_4 , the cause sentence. Thereby, by associating with π_2 , element of π_3 , the syntactic realization of π_3 , A2 is verified for Explanation (π_2, π_4)¹³.

To sum up, the only way to lay down that (18a) involves Explanation and (18b) Result while having axioms A1 and A2 both verified consists in stating that these discourse relations link the DRSs for the cause sentence and the resulting state. The analyses of (18a) and (18b) which take into account these facts are sketched in figures 4 and 5.

Summary on causal discourses

¹³The same kind of argumentation does not work for Result (π_1, π_2) as proposed by Asher and Pustejovsky, since π_1 et π_2 are both elements of π_3 : the only syntactic realizations that can be associated with π_1 and π_2 are not distinct thus not linearly ordered.

We have shown that the causal interpretation of discourses such as (18a) and (18b) is bound to event coreference. Therefore, the discourse relations Particularization and Generalization are also at stake in causal discourses. What is mere Explanation and Result hold neither between the two sentences of the causal discourses nor between the two sub-events of the causative verb. They hold between the DRSs for the cause sentence and the resulting state. The fact that Explanation goes along with Particularization while Result goes along with Generalization allows us to explain why Explanation discourses have a normal behaviour (e.g. any modifier can be inserted) while Result discourses have an awkward behaviour (e.g. heavy constraints on the insertion of modifiers). Explanation and Result are thus not really converse, despite what is generally believed.

4 Conclusion

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