"Discourse Verbs" and Discourse Periphrastic Links

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1 Introduction

There is a number of English or French verbs which take as semantic arguments eventualities or facts[1]. An example is the verb *precede* illustrated in (1a)[2]: its semantic arguments are the CL rise and the rise of blood leucocytes. The content conveyed by (1a) can be alternatively expressed in (1b); in other words, (1a) and (1b) are periphrastic. In (1b), the temporal relation between the CL and leukocyte rise is indicated by the discourse connective *next*.

(1) a. CL start to rise, reaching the maximum level, twice that of healthy controls, on day +11. This preceded the rise of blood leukocytes above 1.0X10(9)1.-1 ...
b. CL start to rise, reaching the maximum level, twice that of healthy controls, on day +11. Next, blood leukocytes rose above 1.0X10(9)1.-1 ...

By analogy with the term "discourse connective", I call verbs such as *precede* "discourse verbs". The subject of this paper is discourse verbs, with the aim to formally establish the periphrastic link between utterances with a discourse connective and those with a discourse verb, see (1a) and (1b).

By definition, periphrastic discourses share the same information content and so should yield to equivalent logical forms in a model-theory approach. Discourse structures, based on discourse relations, constitute an intermediary representation level between discourses and their logical forms. The standard discourse structure for (1a) is $\mathit{Narration}(\pi_1, \pi_2)$[3], π_1 representing the CL rise, π_2 the leucocyte rise. That for (1b) is $Comment(\pi_1, \pi_3)$[4], π_3 representing the temporal precedence relation between the CL and leucocyte rises. These standard discourse structures are quite different: they involve neither the same discourse relation nor the same second argument. So they don't reflect that (1a) and (1b) are periphrastic and a lot of computation is needed to obtain equivalent logical forms from them. The basic idea of this paper is to propose a discourse structure for (1a) which is drastically different from the standard one but from which the periphrastic link between (1a) and (1b) can be easily established.

The discourse framework for this study is SDRT [Asher & Lascarides, 2003], which takes a model-theory approach. In SDRT or λ-SDRT [Amsili & Roussarie, 2004], the semantic lexical entry for a discourse connective lexicalizing the discourse relation *R* includes *R*. Along these lines, I propose that semantic lexical entries for discourse verbs include discourse relations. These lexical entries allow the periphrastic link between discourses such as (1a) and (1b) to be formally and easily established. But, first, we need a formal method for establishing that two discourses are periphrastic. That is the aim of Section 2, in which the foundations for discourse periphrastic rules are laid down (without taking examples involving discourse verbs). Next, we come back to discourse verbs: Section 3 concerns verbs such as *precede* with arguments referring only to events, Section 4 concerns verbs such as *cause* whose subject can refer to an individual, see (2)[5].

(2) a. Ted left. This / #He preceded Sue's arrival.
b. Ted didn't stop joking. This / He caused hilarity among his friends.

[1] The terms "eventuality" and "fact" come from the definition of "abstract objects" given in [Asher, 1993].
[2] This example is taken from the MEDLINE corpus, see http://www.pubmed.gov.
[3] *Narration* can be replaced by *Sequence*.
[4] *Comment* can be replaced by *Continuation*.
[5] At the opposite of (1), (2) and the other examples in the rest of this paper are constructed, and so may sound unnatural.

2 Formal rules for establishing discourses periphrastic links

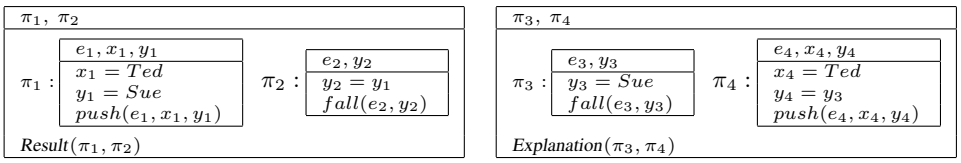
Let us say first that this work concerns multisentential discourse periphrases and not sentential periphrases: sentential periphrases (e.g. *Ted sold Sue a car* $\simeq$ *Sue bought a car from Ted*) are not discussed at all. For discourse periphrases, two cases must be distinguished: one in which the information conveyed appears in the same order in the two periphrastic discourses, the other one in which the order of the information is inverse. The former periphrastic link is noted as $\simeq_1$, the latter $\simeq_2$. Let us start with the latter.

2.1 Periphrastic discourses with inverse information order

Consider the causal discourses in (3), which are periphrastic with (3a) $\simeq_2$ (3b). In (3a), the cause appears before the effect and the discourse relation is *Result*; in (3b), the inverse order of information is at stake and the discourse relation is *Explanation*.

(3) a. Ted pushed Sue. She fell.
b. Sue fell. Ted pushed her.

The representations of these discourses are the SDRSs shown below[6].



The semantics of these SDRSs is respectively the semantics of the "discourse formulae" *Result*(π_1, π_2) and *Explanation*(π_3, π_4). The periphrastic link between (3a) and (3b) leads us to establish the "discourse formula equivalence" *Result*$(\pi_1, \pi_2) \cong_2$ *Explanation*(π_3, π_4). As π_1 and π_4 label equivalent logical forms (they are identical up to variable renaming and anaphoric equations[7]) and as it is also the case for π_2 and π_3, π_1 can be substituted for π_4 and π_2 for π_3 in this equivalence; we obtain: *Result*$(\pi_1, \pi_2) \cong_2$ *Explanation*(π_2, π_1). By abstracting away from the specific examples in (3), we obtain the general discourse formula equivalence *Result*$(\alpha, \beta) \cong_2$ *Explanation*(β, α), which is valid for any α and β.

More generally, I propose to establish periphrastic links between discourses thanks to the notion of discourse formula equivalence ($\cong$), which can be divided into two sub-notions, i.e. $\cong_1$ and $\cong_2$, depending on the preservation of the information order.

The discourse formula equivalence *Result*$(\alpha, \beta) \cong_2$ *Explanation*(β, α) translates the fact that the discourse relation *Explanation* can be considered as the "dual" of *Result*, which is noted *Explanation* = $ANTI$-*Result*[8]. $ANTI$ is a function which equals its inverse function, in other words $ANTI - ANTI$-*R*= *R*. As an illustration, *Explanation* = $ANTI$-*Result* and *Result* = $ANTI$-*Explanation*. Another example of dual discourse relations is illustrated with the periphrastic discourses in (4): the SDRS for (4a) involves *Narration*, while that for (4b) involves a discourse relation called *Precondition* in [Asher, 1993].

(4) a. Ted left. Next, Sue arrived.
b. Sue arrived. Before, Ted (had) left.

The following rules summarize the data put forward in this section.

Equivalence Rule 1 *R*$(\alpha, \beta) \cong_2 ANTI - R(\beta, \alpha)$
$ANTI - ANTI$-*R*= *R*
Explanation = $ANTI$-*Result*
Precondition = $ANTI$-*Narration*

[6] These SDRSs do not represent the temporal information which comes from the verbs. Such information is omitted through the whole paper.

[7] The anaphoric equation $y_4 = y_3$ in π_4 indicates that the pronoun *her* in (3b) refers to the individual named *Sue* ($y_3 = Sue$).

[8] In the terms of [Sanders *et al.*, 1992], *Result* has BASIC order, whereas *Explanation* has NON-BASIC order. The distinction BASIC/NON-BASIC order only applies to causal relations. On the other hand, the function $ANTI$ can take as argument a non-causal relation, for instance *Narration* see below and *Particularization* see Section 2.2.

2.2 Periphrastic discourses with the same information order

Two periphrastic discourses which present the information in the same order should not have the same number of clauses[9]. This situation happens when two clauses in one of the discourse refer to the same eventuality, as it is the case for the first two clauses in (5a). (5b) is a periphrastic discourse with the information conveyed in the same order, but with two clauses instead of three.

(5) a. Ted bought a Ferrari yesterday. He made this purchase just because he loves the red colour.
b. Ted bought a Ferrari yesterday, just because he loves the red colour.

The event coreference relation at stake in the first two clauses of (5a) has been studied in details in [Danlos, 2001], where it is shown that these two clauses should be linked by a discourse relation called *Generalization* which entails an event coreference relation, namely $\textit{Generalization}(\alpha, \beta) \Rightarrow e_\alpha = e_\beta$ (the notation e_α stands for the "main event" of the DRS labeled α)[10]. It goes with the following constraint: the description in β of the event involved should bring no new information compared to its description in α.

The periprastic link between (5a) and (5b) yields the following formula equivalence (π_i labels the DRS for the ith clause): $\textit{Generalization}(\pi_1, \pi_2) \wedge \textit{Explanation}(\pi_2, \pi_3) \cong_1 \textit{Explanation}(\pi_1, \pi_3)$. By abstracting away from this specific example, we get:

Equivalence Rule 2 $\textit{Generalization}(\alpha, \beta) \wedge R(\beta, \gamma) \cong_1 R(\alpha, \gamma)$

The dual relation of *Generalization* is called *Particularization* in [Danlos, 2001]. It is observed between the first two clauses of the discourse in (6a). This discourse relation can be seen as a particular case of *Elaboration*, except that $\textit{Particularization}(\alpha, \beta) \Rightarrow e_\alpha = e_\beta$, while $\textit{Elaboration}(\alpha, \beta) \Rightarrow Part\text{-}of(e_\alpha, e_\beta)$ [Asher & Lascarides, 2003]. It goes with the following constraint: the description in β of the event involved should bring new information compared to its description in α. The periphrastic link between (6a) and (6b) yields Rule 3.

(6) a. Ted made a (peculiar) purchase. He bought a Ferrari, just because he loves the red colour.
b. Ted bought a Ferrari, just because he loves the red colour.

Equivalence Rule 3 $\textit{Particularization}(\alpha, \beta) \wedge R(\beta, \gamma) \cong_1 R(\beta, \gamma)$
$\textit{Particularization} = ANTI\text{-}\textit{Generalization}$

To put it in a nutshell, the semantics of an SDRS being given by the semantics of the discourse formulae it involves, I propose to establish preiphrastic links between discourses thanks to discourse formula equivalences, such as those proposed in Equivalence Rules 1, 2 and 3. Discourse periphrases need to be studied in greater details[11], however let us come back to discourse verbs.

3 Discourse verbs without individual subject

This section examines discourse verbs such as *precede* when its arguments refer both to an event without any possible subject referring to an individual[12]. The semantic lexical entry I propose for *precede* in the active form is given in (7a). It includes the discourse relation *Narration* and should be compared to the lexical entry for *next*, which is given in (7b)[13]. It is instantiated in the SDRS for (8a). (8a) can be paraphrased by

[9] This claim is true if we put aside two discourses which differ only by their discourse connectives (e.g. two synonymous discourse connectives). Recall that sentential (clausal) periphrases are nor taken into account.

[10] The discourse relation *Generalization* is used in [Wolf & Gibson, 2005] in a different way: it links the two sentences in (i), in which no event coreference relation is involved.
(i) Two missions to Mars in 1999 failed. There are many missions to Mars that have failed.

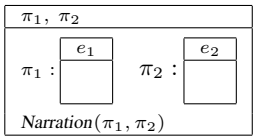
[11] For example, the following phenomenon needs to be taken into account. Discourse (i), in which (3a) is embedded, cannot be felicitously paraphrased by (ii), in which (3b) is embedded, althoug (3a) and (3b) are periphrastic in a null context.
(i) Ted did a somesault. Next, he pushed Sue. She fell.
(ii) ??Ted did a somesault. Next, Sue fell. Ted pushed her.

[12] Sentences such as *Ted preceded Sue in death* are left aside.

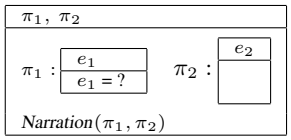
[13] In fact, it seems fruitful to distinguish the types of lexicalization of discourse relations, for example by using superscripts such as $\textit{Narration}^{Verb}$ in the lexical entry of *precede* and $\textit{Narration}^{Conn}$ in the lexical entry of *next*, while keeping the standard notation *Narration* for a discourse relation which is not marked by any lexical item. These distinctions allow us to introduce some nuances, as advocated in [Bras *et al.*, 2001] with the notions of "weak *Narration*" and "strong *Narration*". For example, while $\textit{Narration}^{Conn}$ and *Narration* require a common topic [Lascarides & Asher, 1993], this may be not the case for $\textit{Narration}^{Verb}$. Moreover, the notations R^{Conn}, R^{Verb} and R are quite useful when studying the compatibility between discourse verbs and discourse connectives, see Section 5.

(8b) with the same order of information, (8a) $\simeq_1$ (8b)[14].

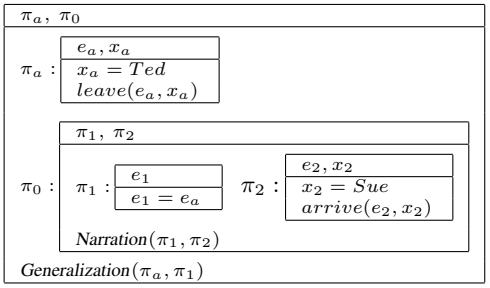
(7a) $\lambda e_1 \lambda e_2$



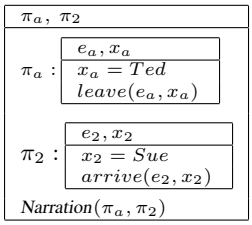
(7b) λe_2



(8a) Ted left. This preceded Sue's arrival.



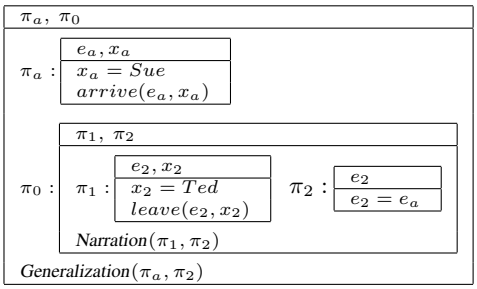
(8b) Ted left. Next, Sue arrived.



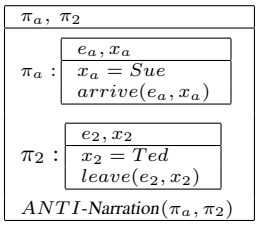
The SDRS for (8a) involves *Generalization*(π_a, π_1), since the main event of π_1 is realized as an anaphor whose antecedent is the main event of π_a, i.e. $e_1 = e_a$[15]. The periphrastic link between (8a) and (8b) can be established thanks to Rule 2 (see Section 2.2) with *R = Narration*.

In (8a), it is the subject of *precede* which is anaphoric. On the other hand, in (9a), it is the object which is anaphoric. (9a) can be paraphrased by (9b) with the same order of information, (9a) $\simeq_1$ (9b)[16]. This periphrastic link yields Equivalence Rule 4.

(9a) Sue arrived. Ted's departure (had) preceded this (arrival).



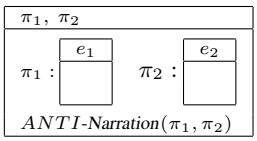
(9b) Sue arrived. Before, Ted (had) left.



Equivalence Rule 4 *Generalization*$(\alpha, \gamma) \ \wedge \ R(\beta, \gamma) \cong_1 ANTI - R(\alpha, \beta)$

We are left with the use of *precede* in the passive form. The semantic lexical entry I propose for *precede* in the passive form is given in (10). It involves the discourse relation $ANTI$-*Narration*, which allows the periphrastic link (11a) $\simeq_1$ (11b) to be formally established thanks to Rule 2.

(10) $\lambda e_1 \lambda e_2$



(11) a. Sue arrived. This was preceded by Ted's departure.
b. Sue arrived. Before, Ted (had) left.

[14] In (8a), Sue's arrival is presupposed, while it is asserted in (8b). However, this difference is ignored here, on the grounds that Sue's arrival is easily accommodated in a null context. On the other hand, the following clause *Ted's departure preceded Sue's arrival* involves two presuppositions which look hard to accommodate in a null context. In other words, this clause should not be uttered as an alternative to (8a) or (8b) in a null context. In a more general way, studying discourse paraphrases requires taking into account the asserted/presupposed content in each discourse.

[15] The SDRS for (8a) could include *Comment*(π_a, π_0). However, this discourse formula is less informative than *Generalization*(π_a, π_1) which specifies where the anaphoric element stands within π_0. In other words, *Generalization*$(\alpha, \beta) \wedge \beta \subset \gamma \Rightarrow$ *Comment*(α, γ), where $\beta \subset \gamma$ means that β is a sub-(S)DRS in γ.

[16] Recall that the periphrastic link (8b) $\simeq_2$ (9b) is established thanks to Rule 1.

However, this raises a problem on the lexical entry of *precede*. For *precede* in the passive form, the standard rules for passive cannot be invoked (very roughly, these rules establish equivalences such as $love(x, y) \cong be - loved(y, x)$). However, the discourse formula equivalence *Narration*$(\alpha, \beta) \cong_2$ *Anti-Narration*(β, α), see Rule 1, can be called upon to link the passive form of *precede* to its active one. The verb *follow* is another discourse verb whose lexical entry in the active form is identical to that of *precede* in the passive form, since (12) is a periphrasis of (11a).

(12) Sue arrived. This followed Ted's departure.

Besides *precede* and *follow*, other discourse verbs in the temporal domain are *coincide* and *succeed* (which can be used in examples such as *there succeeded a period of peace* $\simeq$ *next, there was a period of peace*). On the other hand, outside the temporal domain, there seem to exist few verbs whose arguments can only be eventualities or facts and which can be considered as lexicalizing a discourse relation, let us cite *contrast* or *prove* (*This proves / contrasts with that*), which lexicalize respectively the discourse relations *Contast* and *Evidence*.

4 Discourse verbs with a possible individual subject

Besides discourse verbs such as *precede*, there exist verbs which take both a subject referring to an eventuality or fact and a subject referring to an individual, e.g. *cause*, which is studied here with a nominal complement[17]. (13a) and (13b) can be handled as (8a) and (8b) by substituting *Result* for *Narration*. In (13c), the subject of *cause* refers to the individual Ted; as (13c) is a periphrasis of (13a), (13c) $\simeq_1$ (13d), *he* can be considered as a metonymy of Ted's joking. (13d) is obtained from (13c) by reversing the order of the sentences, so we have (13d) $\simeq_2$ (13c).

(13) a. Ted didn't stop joking. This caused hilarity among his friends.
b. Ted didn't stop joking. As a result, his friends were overcome with hilarity.
c. Ted didn't stop joking. He caused hilarity among his friends.
d. Ted caused hilarity among his friends. He didn't stop joking.

I propose two lexical entries for *cause* in the active form[18]: one when its subject refers to an eventuality or fact (which is modeled on the lexical entry for *precede* by substituting *Result* for *Narration*), the other one when its subject refers to an individual. See below.

$\lambda e_1 \lambda e_2$

π_1, π_2		
π_1 :	e_1	
π_2 :		e_2
Result(π_1, π_2)		

$\lambda x_1 \lambda e_2$

π_1, π_2		
π_1 :	x_1, e_1 $e_1 = ?$ $?pred(e_1, x_1)$	
π_2 :		e_2
Result(π_1, π_2)		

In the entry for *cause* with a subject referring to an individual, the notation $?pred$ stands for an unspecified predicate (whose agent is x_1) which may be specified anaphorically or cataphorically. Let us precise this point in the representations of (13c) and (13d).

(13c)

π_a, π_0		
π_a :	e_a, x_a $x_a = Ted$ $keep - joking(e_a, x_a)$	
π_0 :	π_1, π_2	
π_1 :	x_1, e_1 $x_1 = x_a$ $e_1 = e_a$	
π_2 :	e_2, x_2 $x_2 = friends$ $hilar.(e_2, x_2)$	
Result(π_1, π_2)		
Generalization(π_a, π_1)		

(13d)

π_0, π_a		
π_0 :	π_1, π_2	
π_1 :	x_1, e_1 $x_1 = Ted$ $e_1 = e_a$	
π_2 :	e_2, x_2 $x_2 = friends$ $hilar.(e_2, x_2)$	
Result(π_1, π_2)		
π_a :	e_a, x_a $x_a = x_1$ $keep - joking(e_a, x_a)$	
Particularization(π_1, π_a)		

The SDRS for (13c) involves *Generalization*(π_a, π_1): the unspecified predicate is specified anaphorically and π_1 does not bring new information compared to π_a on $e_1 = e_a$. The SDRS for (13d) involves

[17] The verb *cause* may have an infinitival complement: *Ted caused his friends to be hilarious*.

[18] For *cause* in the passive form, the lexical entries involve the discourse relation *Explanation* = $ANTI$-*Result*

Particularization(π_1, π_a): the unspecified predicate is specified cataphorically and π_a does bring new information compared to π_1 on $e_1 = e_a$. As *Particularization* = $ANTI$-*Generalization*, the periphrastic link (13c) $\simeq_2$ (13d) is obtained thanks to Rule 1[19].

In the literature, (13c) is generally analyzed as *Result*(π_a, π_0). On the other hand, thanks to the SDRS proposed above for (13c) and to Rule 2, we get: *Generalization*$(\pi_a, \pi_1) \wedge$ *Result*$(\pi_1, \pi_2) \cong_1$ *Result*(π_a, π_2), which establishes the periphrastic link (13c) $\simeq_1$ (13b). This is the right analysis for (13c): (Ted's joking)$_{\pi_a}$ is the cause of (the hilarity)$_{\pi_2}$ and not the cause of (Ted causing hilarity)$_{\pi_0}$ (as entailed by the analysis of (13c) as *Result*(π_a, π_0)).

Besides *cause*, there exists a number of causal verbs. On the one hand, there exist other verbs such as *provoke, launch, trigger*, etc., which are quite similar to *cause*. On the other hand, there exist causative verbs which lexically encode the effect. Firstly, psychological causative verbs such as *irritate*, illustrated in (14).

(14) a. Ted didn't stop joking. This / He irritated me.
b. Ted irritated me. He didn't stop joking.

Following the analysis of [Pustejovsky, 1995], a clause *X irritate Y* denotes a complex event made up of a causing sub-event (*X doing something*) and a resulting sub-event (*Y being irritated*). Following the analysis of [Danlos, 2000] for causal discourses such as (14), there is an event coreference relation between the joking event and the causing sub-event of *irritate*: the causing sub-event of *irritate* is specified anaphorically in (14a) and cataphorically in (14b). A psychological causative verb such as *irritate* can be given two semantic lexical entries modeled on those of *cause*, one when its subject refers to an eventuality or fact, and the other one when its subject refers to an individual, see below.

$\lambda e_1 \lambda y$

$\pi_1,\ \pi_2$		
π_1 : e_1	π_2 : $y,\ e_2$	
		$irritated(e_2, y)$
Result(π_1, π_2)		

$\lambda x \lambda y$

$\pi_1,\ \pi_2$		
π_1 : $x,\ e_1$	π_2 : $y,\ e_2$	
$e_1 = ?$		$irritated(e_2, y)$
$?pred(e_1, x)$		
Result(π_1, π_2)		

Secondly, there exist non psychological causative verbs such as *break* illustrated in (15). In the context described here, they behave in the same way as psychological causative verbs, except that $?act{-}on(e_1, x, y)$ should be substituted for $?pred(e_1, x)$ in the lexical entry of a non psychological verb with an individual subject, as advocated in [Pustejovsky, 1995].

(15) a. Ted hit the carafe against the sink. This /He broke it.
b. Ted broke the carafe. He hit it against the sink.

Thirdly, there exist verbal expressions which lexically encode the effect, such as *give a headache* illustrated in (16).

(16) a. Ted didn't stop joking. This / He gave me a headache.
b. Ted gave me a headache. He didn't stop joking.

The verbal expression *give a headache* is the causative for the "light verb" expression *have a headache*. Besides causatives for light verb expressions, there exist causatives for adjectives and prepositional phrases behaving adjectively, illustrated in (17).

(17) a. Ted didn't stop joking. This / He made me nervous / put me in a bad mood.
b. Ted made me nervous / put me in a bad mood. He didn't stop joking.

5 Conclusion

It seems that verbs such as *precede* or *follow* and any causal or causative verb (or verbal expression) can be given (in the active form) one or two lexical entries which include a discourse relation. This allows the various periphrastic links put forward in the paper to be established. These lexical entries can also be very useful when computing SDRSs, see Chapter 6 in [Asher & Lascarides, 2003]. There are two lexical entries when the subject (in the active form) can be both an abstract object (event or fact) and an individual.

[19] With Rule 1, we have: *Generalization*(π_a, π_1) $\wedge$ *Result*$(\pi_1, \pi_2) \cong_2$ *Particularization*(π_1, π_a) $\wedge$ *Result*(π_1, π_2).

There is one entry when the subject can only be either an abstract object (this is the case for *precede*) or an individual (this is the case for the French verb *casser* which translates *break*[20]). When there are two lexical entries for the same verb, they should be linked in the spirit of the Generative Lexicon [Pustejovsky, 1995], especially since the use with an individual subject is understood as a metonymy of the use with an abstract subject.

I have introduced the term "discourse verb" in Section 1 for *precede* with two abstract arguments because of the periphrastic link between utterances with a discourse connective and those with a discourse verb. The same term can qualify verbs such as *break* or *casser*, even when they are used with individual arguments. However, there is the following difference. The verb *precede* is totally incompatible with the use of *next*: (18a) is distinctly odd. On the other hand, *break* with an individual subject is not incompatible with a discourse connective: (18b) and (18c) could be accepted.

(18) a. #Ted left. Next, this preceded Sue's arrival.
b. ?Ted hit the carafe against the sink. As a result, he broke it.
c. ?Ted broke the carafe because he hit it against the sink.[21]

If a discourse verb is defined as a verb whose lexical entry(ies) includes a discourse relation R[22], then the question whether a discourse verb is compatible with a discourse connective lexicalizing the same discourse relation R is open and perhaps the answer is not the same in French and in English. As far as I am aware, (19a) in English sounds better that its French translation in (19b).

(19) a. ??Ted didn't stop joking. As a result, this caused hilarity among his friends.
b. #Ted n'a pas arrêté de plaisanter. Par conséquent, ceci a causé l'hilarité de ses amis.

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[20]The French translation of (15a) is (i) which is impossible with *ceci*. However, in a loose style where *ça* is used instead of *ceci*, *ça l'a cassée* sounds better.
(i) Ted a heurté la carafe contre l'évier. #Ceci / Il l'a cassée.

[21]The discourses *Ted broke the carafe by hitting it against the sink.* and *Ted broke the carafe when he hit it against the sink.* are natural.

[22]In RST, a verb such as *say* could have a lexical entry which includes the discourse relation *Attribution* since in [Wolf & Gibson, 2005] for example, this discourse relation is used in an example such as (i) in which discourse segment 1 states the source of what is stated in discourse segment 2. However, a verb such as *say* has nothing in common with the discourse verbs studied here.
(i) (John said that)$_1$ (the weather would be nice tomorrow.)$_2$