Where's the Meeting that was Cancelled? Existential Implications of Transitive Verbs

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ABSTRACT
This paper describes a preliminary classification of transitive verbs in terms of the implications of existence (or non-existence) associated with their direct object nominal arguments. The classification was built to underlie the lexical marking of verbs in the lexical resources that the automated system BRIDGE developed at Xerox PARC used for textual inference. Similar classifications are required for other logic-based textual inference systems, but very little is written about the issue.

KEYWORDS: textual inference, lexical resources, transitive verbs.

1 Motivation

A computational system cannot be said to understand natural language if it cannot draw some rather direct inferences from a text. Central among them are inferences about the existence or non-existence of the entities and eventualities referred to. In this paper we look at two types of referentially opaque transitive verbs: verbs that are inherently negative and thus imply non-existence, and verbs with what we could call time-dependent opacity.

In our discussion we make the simplifying assumption that the reader/the system considers the speaker trustworthy so that anything that the speaker is committed to as being true (or false) by virtue of the linguistic expression used, is treated as true (or false). Our notion of speaker commitment covers both entailments and presuppositions/implicatures (see (Karttunen and Zaenen, 2005) for a short discussion and (Potts, 2005) for an extensive motivation.)

The detection of existential implications is an essential part of computing textual inferences, as conceived, for instance, in the RTE (Recognizing Textual Entailment) Pascal challenge (Dagan et al., 2006). A simplified example is given in (1).

(1) Ed built a spacious hut. There was a spacious hut. YES

Our inquiry and classification extends (Nairn et al., 2006), which looks at implicative verbs with clausal complements. The relation between the two problems can be seen by comparing the implications of the verb 'prevent' construed with a clausal complement or a nominal (event-denoting) complement:

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(2) Ed prevented Mary from leaving. Mary left. NO

(3) Ed prevented an accident. There was an accident. NO

The work reported here, as the one in (Nairn et al., 2006) and elsewhere, takes the view that *inferential* aspects are one of the main challenges that lexicographers interested in cognitive features of the lexicon need to address.

The treatment proposed in (Nairn et al., 2006) aims at capturing the author's commitment to the truth or falsity of the complement clause of the verb. This classification is based both on the semantics of the complement-taking verb and on the syntactic type of the clause (e.g. factive *forget that* vs. implicative *forget to*). In the case of nominal complements, different factors need to be taken into consideration to determine the speaker's commitment to the existence or non-existence of the denotation of the complement of the verb. These include:

- syntactic alternations of the verb,
- the aspectual class of the verb phrase,
- whether the nominal complement is event-denoting or not,
- the aspectual properties of the nominal complement if it is event-denoting
- the tense and aspect of the verb.

A final factor is the (in)definiteness of the direct object. Definite NPs tend to presuppose the existence of their referents. We will try to control for this by constructing examples with indefinite NPs. Further complications will be discussed in the relevant sections.

2 Constraints on the classification

The classification was conceived to be used in conjunction with the representations produced by the automated system BRIDGE (Bobrow et al., 2007a),(Bobrow et al., 2007b). An important feature of these representations is the *(un)instantiability* of *concepts*, which corresponds to a claim of (non-)existence of an entity or occurrence of an event denoted by the concept. For instance, the sentence "Negotiations prevented a strike" involves events of the type "negotiation", "strike" and "preventing". Intuitively, the negotiations (whatever they may be) are presented as having occurred in the real world and so is the preventing event. In our representation, the terms corresponding to the words "negotiations" and "prevented" are instantiated in the top context, which corresponds to what the author of the sentence considers as true. But the term corresponding to "strike" should only be instantiable in the prevent-context; in the top context the term should be declared uninstantiable. See (Condoravdi et al., 2001), (Crouch et al., 2003) for motivation and details. The use of contexts, which correspond logically to partial possible worlds, allows us to represent further aspects of the situation prevented (for instance, how long that strike would have been or how bitter, etc.) without running into contradictions.

The BRIDGE system, by default, treats the nominal arguments of verbs as carrying existential commitments at least in the context of the predication. This is obviously inadequate for the phenomena that we discuss in this paper and in section 5 we will propose an extension of the system that allows us to treat these phenomena more adequately.

3 Criteria for the classification

The main criterion adopted in the classification of the verb classes is whether the verb meaning indicates or does not indicate that the referent of the direct object existed before the eventuality denoted by the verb took place (pre-state) or not and whether the referent of the direct object exists after this eventuality (post-state). We focus on verbs that affect the existence of its object; for example, *annul* meets this description, but *touch* does not; only in the former case is the change with respect to the existence of the referent of the direct object part of the meaning of the verb. This difference in the implications that we intend to capture is exemplified in the contrast between (4) and (5):[1]

(4) Ed touched a teapot.
Pre-state: There was a teapot. YES
Post-state: There is a teapot. YES

(5) The judge has annulled Ed's marriage.
Pre-state: Ed was married. YES
Post-state: Ed is married. NO

We will call verbs that indicate a change in the existence of the referent of their nominal complement, existential change verbs. In this paper we focus on this type of verbs and leave aside verbs that do not encode pre- and post–states (or with pre- and post–states that are the same). We present the different types of existential change verbs in the next section. In section 5, we discuss the representation of information about existence in our system.

4 Existential change verbs

In this class we identified eight sub-classes. They can be subdivided broadly into verbs of causation (the first five subclasses) and aspectual verbs (the last three subclasses).

4.1 *Cause*-type verbs

In this subsection we look at verbs whose nominal complement is headed by a noun that denotes an eventuality. Examples are *cause*, *provoke*, *force*, *produce*, *bring about*, *induce*. They share the following implications: (i) In positive environments: the predicate entails the occurrence of an eventuality/situation as a post-state, (ii) the caused eventuality/situation does not exist in the pre-state, (iii) in negative environments it is unknown whether the caused eventuality/situation has taken place. This indeterminacy is due to the indeterminacy of the scope of the negation. This pattern of inferences is exemplified in (6) and (7):

(6) The decree caused trouble.
pre-state: There was trouble. NO
post-state: There was trouble. YES

[1] This representation of the lexical meaning of verbs abstracts away from many factors that may intervene in a factual situation. For instance, (5) may be used in a case where Ed has gotten married again.

(7) The decree didn't cause trouble.
pre-state: There was trouble. UNKNOWN
post-state: There was a trouble. UNKNOWN

Similarly, in (8), under normal circumstances, the speaker is committed to the non-occurrence of the revolution before the decree and to its occurrence after the decree.

(8) The decree caused a revolution.
pre-state: There was a revolution before the decree. NO
post-state: There was a revolution after the decree. YES

When the progressive is used we find some cases of the "Imperfective Paradox"((Dowty, 1979)), whereas in others there seems not to be such effect. Compare (9) and (10):

(9) The decree was causing trouble when it was revoked.

(10) The decree was causing a revolution when it was revoked.

Whereas in the first example we conclude that there was trouble (i.e., the decree has caused some trouble), in the second we conclude that a revolution was avoided. We hypothesize that this is due to the nature of the eventuality that the nominal refers to. It is well-known that eventualities can be 'homogeneous' (states and processes) or not (accomplishments and achievements). 'Trouble' is homogeneous: a little bit of trouble is trouble but 'revolution' is not: for instance, the beginning of a revolution is not a revolution.

Cause–type verbs can also be used to express a change of degree rather that a change from non-existence to existence as exemplified in (11).

(11) The medicine induced an increase in blood pressure.
pre-state: There was an increase of blood pressure. NO
post-state: There was an increase in blood pressure. YES

Here the event that occurs is not the coming into existence of blood pressure but the increase in it. That is, of course, as expected: here the caused eventuality is the increase.

4.2 Verbs of creation

Closely related to the previous class are verbs of creation. They are different in that their complement refers to an object (physical or not) and not to an eventuality. This class includes verbs like *build*, *bake* (as in 'bake a cake'), *write*, *coin*, *compose*, *compute*(as in 'compute a solution'), *concoct*, *construct* (see Create verbs 24.4 and 24.1 in (Levin, 1993)) with the following cluster of implications: (i) in positive environments, there is a speaker's commitment to the non-existence of the object before the event (entailment), and (ii) a commitment to the existence of the object after the event in the simple past tense, (iii) in negative environments, it is unknown whether the object exists, all we know is that the referent of the subject of the sentence did not bring it into existence.

(12) John built a house.
There is a house.YES

(13) John didn't build a house.
There is a house. UNKNOWN

The effect of the "Imperfective Paradox", however, is much stronger with these verbs than with the previous class: in positive environments, the use of the progressive form changes the speaker's commitment as to the existence of the object. Therefore, we need a conditional marking in the rules, i.e. if the verb occurs in the simple past, the speaker is committed to the existence of the object, and if the verb occurs in the progressive, the speaker is committed to the non-existence of the object.

(14) John is building a house.
There is a house. NO

Verbs like *draw*, *picture*,*sculpt* etc. behave like verbs of creation when their nominal complement denotes the material or eventive result (*draw a picture, sing a song*). But they belong in the class of intensional verbs when their nominal complement denotes the content of the act: because what you draw may or may not exist in the real world (e.g. *draw a unicorn*).

4.3 Verbs of destruction

Verbs like *destroy*, *extinguish*, *terminate*, *annul*, *invalidate*, *nullify*, *break off*, *annihilate*, *demolish*, *undo*, *wreck*, *resolve*, share the following cluster of implications: In positive environments, (i) the speaker is committed to the existence of the object before the event (entailment) and (ii) the speaker is committed to the non-existence of the object after the event (entailment), and (iii) in negative environments, there is no commitment as to the existence of the object, but in common usage the speaker seems to be committed to the existence of the object (plausible, not strict inference). This is exemplified below:

(15) The firefighters extinguished a fire.
pre-state: There was a fire. YES
post-state: There is a fire. NO

(16) The firefighters didn't extinguish a fire.
pre-state: There was a fire. UNKNOWN
post-state: The fire continues. UNKNOWN
(The firefighters didn't extinguish the fire, but the rain did.)

The following two classes of verbs differ from the previous ones in that there is a modal component to their meaning; the nominal complement of the verb may denote either an eventuality that is true in the actual world or whose existence is restricted to a possible world other than the actual world.[2]

[2]Speakers' commitments of existence (or non-existence) allowed by the verbs presented in sections 4.4 and 4.5 may receive a morphological marking.

4.4 *Avoid*-type verbs

Verbs like *avoid*, *elude*, *escape*, whose meaning can roughly be paraphrased as 'manage not to experience something evaluated as bad', share the following cluster of implications when the nominal denotes an eventuality: In positive environments, (i) the speaker is committed to the potential occurrence of the eventuality denoted by the nominal complement before the event, and (ii) these verbs allow for both a wide and a narrow scope interpretation: in the wide scope interpretation, the speaker is committed to the occurrence of the eventuality after the event, and in the narrow scope interpretation, the speaker is committed to the non-occurrence of the eventuality after the event. (iii) In negative environments, the speaker is committed to the occurrence of the eventuality after the event.

This is exemplified below for *avoid*:
Narrow scope reading:

(17) So here's some good news about how hundreds of workers avoided a layoff and didn't lose the jobs to downsizing ...

pre-state: There was a potential layoff. YES
post-state: There was a layoff. NO

Wide scope reading:

(18) We landed in Lima only to find that yet again we had narrowly avoided an earthquake (Tokyo all over again). This one was a massive quake of around 7-8 on the richter scale ...

pre-state: There was a potential earthquake. YES
post-state: There was an earthquake. YES

Note that we are concerned here with the inferences that are licensed by the lexical meaning of *avoid*. What has changed between the pre–state and the post–state is precisely the speaker's commitment as to the existence of the eventuality denoted by the nominal complement of the verb in the post–state: the non-occurrence of the eventuality in (17) and its occurrence in (18). When the nominal dependent denotes an object rather than an event, the object is assumed to exist in the pre- and in the post–state (wide scope reading):

(19) We avoided a tree.
pre-state: There was a tree. YES
post-state: There was a tree. YES.

When the nominal complement's direct denotation is an object, by semantic coercion the complement is interpreted as denoting an eventuality:

(20) We avoided a tree.
We avoided hitting a tree.
We avoided the ball.
We avoided being hit by the ball.

The direct denotation of these objects is assumed to exist before and after the act of avoidance but the eventuality described in the expansions is asserted not to take place.

4.5 *Prevent*-type verbs

Verbs like *prevent*, *avert*, *block*, *inhibit*, *impede*, *hinder*, *deter*, *preclude*, *forbid*, *forestall*, and *cancel* (in the sense of 'cause not to','prevent from happening'), *spare* (in the meaning 'refrain from harming') share the following cluster of implications: In positive environments: (i) the speaker is committed to the potential existence of the object before the event, and (ii) the speaker is committed to the non-existence of the object after the event, (iii) there is a causal implication, and (iv) in negative environments, the speaker is committed to the existence of the object (plausible inference, seems to be the common usage). The nominal complement of this class of verbs is event-denoting.

(21) The government prevented an oil spill in the bay.
post-state: There was an oil spill in the bay. NO

(22) And nobody questions him because this mayor of a large American city who didn't prevent a major terrorist attack but seemed emotional in its aftermath has some special insight into the nature of terrorism . . .
post-state: There was a major terrorist attack. YES

4.6 *Begin*-type verbs

This class includes aspectual verbs like *begin*, *start*, *initiate* that denote the beginning of an eventuality. When the referent of the nominal complement is an eventuality, these verbs share the following cluster of implications: (i) in positive environments, there is a speaker's commitment as to the non-occurrence of the eventuality before the event (entailment), and (ii) there is no commitment as to the occurrence of the eventuality after the event; (iii) in negative environments, there is a commitment as to the non-occurrence of the eventuality after the event. We illustrate (i) in (24), 25, and (23)):

(23) Ed and Mary didn't begin a relationship.
pre-state: There was a relationship. NO

(24) Ed and Mary began a relationship.
pre-state: There was a relationship. NO

(25) The queen began a visit to India.
pre-state: There was a visit. NO

The status of (ii) depends on the properties of the eventuality referred to by the nominal complement. We hypothesize that the same distinction as discussed above in subsection 4.1 holds here too: when the eventuality is homogeneous, there is an existence commitment, when it is not, there is no commitment. Compare (26) and (27):

(26) Ed began a trip to Paris.
post-state: Ed made a trip to Paris. UNKNOWN
The queen began a visit to India.
post-state: The queen made a visit to India. UNKNOWN

(27) Ed and Mary began a relationship.
post-state: There was a relationship. YES
A boy playing with matches started a Southern California wildfire.
post-state: There was a wildfire. YES

Adapting test for verbs we can illustrate the difference between the nouns in (26) and (27) as follows:

(28) #They had a relationship in 2 months.
#There was a wildfire in two weeks.
They made a trip to Paris in 2 weeks.
They made a visit to India in two weeks.

As is the case with verbs, homogeneous events do not take temporal modifiers that express the duration, whereas accomplishments do.

When the verbs in this class take a nominal complement which is not event–denoting, as is the case of 'book' in (29), semantic coercion changes the denotation to an eventuality. As has been argued inter alia in (Pustejovsky, 1995), a sentence like (29) is ambiguous (at least) between 'starting to write a book' and 'starting to read a book'. As the combination of the verb and the nominal complement does not tell us which reading we have to choose, and this choice bears on the existential commitment about the object (see (30) and (31)), we mark the implications of (29) as UNKNOWN.

(29) John started a book.
pre-state: There is a book.UNKNOWN
post-state: There is a book. UNKNOWN

(30) John started to write a book.
pre-state: There is a book. NO
post-state: There is a book. UNKNOWN

(31) John started to read a book.
pre-state: There is a book. YES
post-state: There is a book.YES

In negative environments, the entailments are the same regardless of whether the denotation of the complement is an object or an eventuality.

4.7 *Continue*-type verbs

Verbs like *continue* and *pursue*, which we don't illustrate here, share the following cluster of implications: (i) the speaker is committed to the occurrence of the eventuality in the pre–state (presupposition), (ii) in positive environments, the speaker is committed to the occurrence of the eventuality in the post–state (entailment), (iii) in negative environments, there is a speaker's commitment as to the non-occurrence of the eventuality in the post–state. As with the previous class the implications depend on the aspectual class of the noun.

4.8 *End*-type verbs

Examples of end-type verbs are *end*, *stop*, *cease*, *finish*, *discontinue*, *suspend*, *interupt*. When the direct denotation of their nominal complement isn't an eventuality, its interpretation is coerced to an eventuality reading as is the case with begin and continue-type verbs. The end-type verbs share the following cluster of implications: (i) In positive environments, the speaker is committed to the non-occurrence of the eventuality after the end-event (entailment), and (ii) in negative environments, there is no commitment as to the occurrence of the eventuality, but in common usage the speaker seems to be committed to the occurrence of the eventuality after the end-event (plausible, not strict inference).

Again, these verbs, as well as *interrupt* and *discontinue*, have different entailments depending on the aspectual properties displayed by the nouns that they take as complement. With nouns that denote activities, the speaker is committed to the existence of the activity, whereas this is not the case for nouns denoting accomplishments (or achievements):

(32) Ed interrupted a discussion between the students.
pre-state: The students had been discussing. YES
post-state: There was a discussion between the students. NO

(33) Ed stopped the bleeding.
pre-state: There was a bleeding. YES
post-state: There is bleeding. NO

(34) John stopped the evaluation of the system.
pre-state: There was an evaluation of the system. NO
post-state: The system was evaluated. NO

However, we must further distinguish between two sub-classes within this class of verbs. The verbs *end* and *finish* behave differently from *stop* with accomplishment predicates:

(35) Ed stopped a repair.
post-state: There was a repair. NO

(36) Ed ended/finished a repair.
post-state: There was a repair. YES

But this is not the case for nouns that denote activities or states, where both *end* and *stop* display the same pattern of implications:

(37) The president ended/stopped a war.
post-state: There is a war. NO

With respect to nominals whose primary denotation are objects, the interpretation depends again on the eventuality to which the interpretation of the nominal is plausibly coerced. For example, in (38) what is understood to have stopped is the ticking of the clock. Again *finish* and *end* behave differently.

(38) John stopped a clock.
post-state: There is a clock. YES

(39) Ed didn't finish a dissertation.
post-state: There is a dissertation. NO

It is clear, then, that the entailments of sentences containing aspectual verbs like *start*, *continue*, *end* and *stop*, among others, depend on the aspectual properties of the nouns that they take as complements. For event-denoting nouns that are not deverbal (e.g. crime, accident, earthquake, ceremony, game, violence) little is known about these properties.

5 Representing existence information

Representation of the kind of information within the system BRIDGE is mediated by the relevant lexical information being imported into the Unified Lexicon (UL) (Crouch and King, 2005). Similarly to complement taking implicative verbs (Nairn et al., 2006), we expect to mark by hand the new implication signatures discussed, using some frequency criteria. We envisage using the British National Corpus (BNC) frequency list to uncover transitive verbs with these new kinds of implicative behavior. The appropriate lexical markings would then trigger rules constructing representations that encode the corresponding implications. We also envisage leveraging some of the Verbnet semantics information to check our proposed pre and post conditions.

Notions of pre- and post conditions are widely used in logics for verification of programs, in the so-called Hoare logics. These kinds of conditions are also used in AI planning and in formal models of concurrency. However, they have found little use in semantics of natural languages. We propose to use these conditions as a first approximation for the inferential meaning of verbs.

6 Conclusion

The present investigation of existential implications of transitive verbs shows that any implementation of logic-based textual inference needs to take into consideration different types of factors: the implicative behavior of a set of transitive verbs as a function of their lexical meaning, tense and aspect of the verbs, aspectual properties of the nominal complements, and definiteness. The combination of these factors as clues for the identification of the commitment of the speaker with respect to the existence of the entity or event denoted by the nominal complement of the verb is a challenge for any Entailment and Contradiction Detection system.

Our attempt to spell out the existential inferences leads to theoretical problems: it shows that we need an ontological classification of the nominal complements in eventuality-denoting and object-denoting, that we need a coercion mechanism for the object-denoting nouns and

a distinction between the existential implications for the denoted object and for the denoted coerced eventuality and it forces us to look at the ill-understood aspectual properties of eventuality-denoting nouns whether they are morphologically deverbal or not.

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