Negation in event semantics with actual and nonactual events

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The goal of this work is to provide a formal account of negation in a Davidsonian framework that (i) makes negative events available for the analysis of various constructions that are otherwise problematic (such as negative naked infinitives or adverbial modification) and (ii) exhibits reasonable logical properties. This is done by first distinguishing between actual and non-actual events and then introducing a Neg function sending any event-predicate P to *the not-P event* and obeying a single axiom.

1. Introduction

In event-based semantics (Davidson 1967b), action verbs (e.g, *walk*) have an implicit semantic argument that is interpreted as the event described by the verb, in addition to the traditional ones (e.g., the walker). The principal motivation for this move was its ability to treat adverbial modifications in the same fashion as adjectival ones, namely in a conjunctive way which immediately accounts for inferences such as:

(1) *Mary left suddenly.* $\Rightarrow$ *Mary left.*

Unfortunately, event semantics faces serious problems when dealing with negation, both at the syntax-semantics interface and at the purely semantics level itself. In this article, it is argued that these difficulties originate from the standard analysis of negation (henceforth 'SAN') in event semantics, according to which a negative sentence is interpreted as stating the non-existence of any event of some kind (for instance, $[\![\text{Mary did not leave}]\!] = \neg\exists e.\ [\![\text{Mary leave}]\!](e)$), in contrast with positive sentences which assert the existence of some events.

Rejecting this view, I take negative verbal projections to introduce events, the so-called *negative-events*. While this idea is not new (Higginbotham 1983; Peterson 1997; Przepiórkowski 1999), it has never been fully formalised. The main contribution of this article is thus a formal definition of negative events that (i) are relevant to the analysis of various constructions such as perception reports or adverbial modification and (ii) exhibit reasonable

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logical properties.

The text is organised as follows. Section 2 introduces event semantics and (some of) the issues encountered and questions raised when dealing with negation. Then, in Section 3, a couple of relevant alternatives to the SAN are discussed, namely Krifka (1989)'s maximal events and Higginbotham (1983, 2000)'s negative predicates. After that, I will present in Section 4 how a distinction between actual and non-actual events allows for a definition of negative events as the result of applying a Neg function to a set of events; the logic of these negative events will also be studied. Then, I will show in Section 5 how this definition can be used in the analysis of constructions that otherwise remained problematic in event semantics, before reviewing the main arguments that have been written against negative events.

2. Event semantics

2.1. What and why

It is usual, in the Montagovian tradition (Montague 1970), to represent the semantic contribution of a verb as a predicate with an arity equal to the number of syntactic arguments of this verb. Hence, the intransitive verb *walk* is represented as a unary predicate $walk : \langle e, t\rangle$, which allows one to represent the semantics of the sentence (2-a) as the logical formula in (2-b):

(2) a. Mary was walking.
b. $walk(Mary)$

One problem with this analysis regards verbal modification, as in the following sentence:

(3) Mary was walking at noon.

Montague models a modifier such as *at noon* with a predicate modifier $at\_noon : \langle\langle e, t\rangle, \langle e, t\rangle\rangle$ that turns the predicate $walk : \langle e, t\rangle$ into another predicate, $at\_noon(walk) : \langle e, t\rangle$. Sentence (3) can thus be represented as formula (4):

(4) $at\_noon(walk)(Mary)$

As is, however, this formula does not account for the natural entailment from sentence (3) to sentence (2-a). This can be solved by introducing a meaning postulate relating the interpretation of all entity predicates to their image by at_noon:

(5) $\forall x, P.\ at\_noon(P)(x) \rightarrow P(x)$

This solution works, but might be seen as inelegant as it relies on the introduction of not only one meaning postulate per such modifier, but much more if one aims at accounting for the logical equivalence of their various combination:

(6) a. (i) Mary was walking at noon in the park.
(ii) $in\_the\_park(at\_noon(walk))(Mary)$
b. (i) Mary was walking in the park at noon.
(ii) $at\_noon(in\_the\_park(walk))(Mary)$

Another possible way to represent the semantics of sentence (3) requires the introduction of a

new predicate *walk*, with an additional time argument:

(7) $[\![(3)]\!] = walk(Mary, noon)$

Unfortunately, this solution is even less economical than the previous one in terms of meaning postulates and predicates.

Alternately, the intuition behind event semantics is that sentence (3) states that there exists some event with two properties: it is a walking by Mary, and it happened at noon. This observation lead Davidson (1967b) to propose that action verb predicates simply have an *implicit event argument* in addition to the ones corresponding to the syntactic arguments of the verb. Now, sentences (2-a) and (3) are represented as:

(8) a. $[\![(2\text{-a})]\!] = \exists e.\ walking(e, Mary)$
b. $[\![(3)]\!] = \exists e.\ walking(e, Mary) \wedge at\_noon(e)$

These representations involve the same $walk : \langle v, \langle e, t\rangle\rangle$ predicate and account immediately for the entailment from sentence (3) to sentence (2-a) through the logical properties of conjunction, without the need of any meaning postulate. In addition, event semantics naturally scales to any number of verbal modifications, as shown in the following example from Davidson (1967b):

(9) a. Jones buttered the toast in the bathroom with a knife at midnight.
b. $\exists e.\ butter(e, Jones, the\_toast) \wedge in\_the\_bathroom(e) \wedge with\_a\_knife(e) \wedge at\_midnight(e)$

It is interesting to note that in event semantics, verbs are treated similarly to nouns and adverbs are treated similarly to adjectives. In particular, it is the same *intersective* logical property that was used to predict that *Mary owns a red bike* entails *Mary owns a bike* (10) that now is also used to predict that sentence (3) entails sentence (2-a).

(10) a. $\exists x.\ bike(x) \wedge red(x) \wedge own(Mary, x)$
b. $\exists x.\ bike(x) \wedge own(Mary, x)$

Two additional remarks. First, while Davidson conceived events as having a spatial and a temporal extension, his proposal has been subsequently extended to states (such as owning something or being happy; Parsons 1990) and more abstract objects. For instance, because one natural interpretation of *The Titanic sinking rapidly caused great loss of life* is that it was the rapidity of the sinking, more than the sinking itself, that was the cause of the great loss of life, Peterson (1997) introduces a sinking event e and another 'event' e' for the rapidity of e; e' can then be put in causal relation with the semantic object reifing the great loss of life. Second, in the remainder of the text, the *neo-Davidsonian* analysis is followed (Parsons 1990): under this view, verb denotations are one-place predicates over events only (e.g., $walk : \langle v, t\rangle$) and the usual arguments are related to the event *via* thematic roles (`Ag`, `Th`, `Exp`, etc.):

(11) $[\![\text{Mary was walking}]\!] = \exists e.\ walk(e) \wedge \texttt{Ag}(e) = Mary.$

2.2. Negation

Accounting for negated sentences in event semantics is notoriously difficult (Champollion 2011; Winter & Zwarts 2011; de Groote & Winter 2014). The standard analysis of negation (SAN) in event semantics takes a negative sentence such as (12-a) to express the *non-existence* of any event of the type described by the corresponding positive sentence, i.e., (2-a):

(12) a. Mary was not walking.
b. $\neg\exists e.\ walk(e) \wedge \texttt{Ag}(e) = Mary$

In such an analysis, the negation scopes over the event quantifier. This feature is of utmost importance, as reversing the two operators ($\exists e.\ \neg walk(e) \wedge \texttt{Ag}(e) = Mary$) results in the assertion of the existence of an event that is not a walking by Mary — a (quasi-)trivial statement that is not a possible interpretation of the sentence. The position of the event quantifier is not only an issue with respect to negation, but also with quantified NPs, as in (13):

(13) a. Everybody danced.
b. $\forall x.\ someone(x) \rightarrow \exists e.\ dance(e) \wedge \texttt{Ag}(e) = x$

The problem of compositionally predicting the correct position of the event quantifier has been dubbed the 'Event Quantification Problem' (EQP) by Winter & Zwarts (2011). As they explain, the problem can be seen as resulting from a mismatch between the type of verbs, which denote sets of events, and those of logical operators, which are defined in the propositional domain. In short, the puzzle is: if verbs denote sets of events while negation and quantifiers apply to propositions, what are the mechanisms involved in the derivation of negated and quantified sentences (at least, some verbal element must be converted to a logical proposition at some point)? A few kinds of solutions resolve or avoid this mismatch:

1. Redefining the logical operators so that they work with sets of events, as is done by Krifka (1989) who presents a term that does not turn a proposition into its logical negation, but a set of events into a well chosen set of events that is shown to capture some of the aspects of negation.

2. Interpreting verbal projections (i.e., verbal elements, from the verb up to the sentence level) not as sets of events (type $\langle v, t\rangle$), but as generalised quantifiers over events (type $\langle\langle v, t\rangle, t\rangle$). Champollion (2015) shows that then, the meaning of (linguistic) negation and quantifiers can be straightforwardly defined from their usual logical counterpart (i.e., $\neg$, $\forall$, etc.) without having to introduce any new notion (as is done by Krifka).

3. Having a clear separation in the grammar between two types of verbal projections, lower ones dealing with sets of events and higher ones dealing with propositions and to which logical operators apply, an *existential closure* term bridging the two (Winter & Zwarts 2011; de Groote & Winter 2014). In this approach, the problem is solved by formalising how the grammar introduces the existential closure at its correct position.

The latter two are elegant options concerning the syntax-semantic interface but do not question the SAN. Yet, this analysis also leads to results that are not entirely satisfying at the semantic level itself. Indeed, many constructions that can be straightforwardly analysed in event

semantics when no negation is involved suddenly pose problem once a negation is present. The remainder of this section reviews a few.

Causal statements In the spirit of Davidson (1967a), sentence (14-a) can be interpreted as stating a causal relation between the tiredness of Mary and her partying, an analysis accurately transcribed in formula (14-b).

(14) a. Mary is tired because she partied (last night).
b. $\exists e_1.\ \mathit{tired}(e_1) \wedge \mathtt{Exp}(e_1) = \mathit{Mary} \wedge \exists e_2.\ \mathit{party}(e_2) \wedge \mathtt{Ag}(e_2) = \mathit{Mary} \wedge \mathit{cause}(e_1, e_2)$

However, when the cause or the effect is expressed with a negation, the SAN is such that no corresponding event is available for the causal relation, as illustrated in (15-a). Does this mean that the event-based analysis of causal statements is wrong? Not only was that analysis intuitively very appealing, but it has also been used to model other semantic phenomena such as some pseudoscope effects (Kratzer 1998). So, if it is not altogether wrong, why would it be only valid on the positive cases?

(15) a. Mary is tired because she did not sleep (well).
b. $\exists e_1.\ \mathit{tired}(e_1) \wedge \mathtt{Exp}(e_1) = \mathit{Mary} \wedge (\neg\exists e_2.\ \mathit{sleep}(e_2) \wedge \mathtt{Ag}(e_2) = \mathit{Mary}) \wedge \mathit{cause}(e_1, ???)$

Perception reports According to Higginbotham (1983), a *naked infinitive* involved in a perception report existentially quantifies over an event — this event being the object of the report in question. While positive cases lend themselves easily to this idea (16), negative ones resist, at least if the SAN is followed (17).[1]

(16) a. I saw Mary leave.
b. $\exists e_1.\ \mathit{leave}(e_1) \wedge \mathtt{Ag}(e_1) = \mathit{Mary} \wedge \exists e_2.\ \mathit{see}(e_2) \wedge \mathtt{Exp}(e_2) = I \wedge \mathtt{Th}(e_2) = e_1$

(17) a. I saw Mary not leave.
b. $(\neg\exists e_1.\ \mathit{leave}(e_1) \wedge \mathtt{Ag}(e_1) = \mathit{Mary}) \wedge \exists e_2.\ \mathit{see}(e_2) \wedge \mathtt{Exp}(e_2) = I \wedge \mathtt{Th}(e_2) = ???$

Intersective adverbs Some adverbs such as *(un)fortunately* or *(un)expectedly* enter in negative constructions as well as in constructions without negation (Przepiórkowski 1999). Analysing them as event predicates accounts for the entailment patterns observed in positive constructions but does not seem compatible with the SAN, as illustrated in (18):

(18) a. (i) Unexpectedly, Mary left. ⇒ Mary left.
(ii) $\exists e.\ \mathit{unexpected}(e) \wedge \mathit{leave}(e) \wedge \mathtt{Ag}(e) = \mathit{Mary} \Rightarrow \exists e.\ \mathit{leave}(e) \wedge \mathtt{Ag}(e) = \mathit{Mary}$
b. (i) Unexpectedly, Mary did not leave. ⇒ Mary did not leave.
(ii) $??? \Rightarrow \neg\exists e.\ \mathit{leave}(e) \wedge \mathtt{Ag}(e) = \mathit{Mary}$

[1] Not only do the semantics and philosophy literatures mention such negative perception reports (Barwise & Perry 1981; Higginbotham 1983) but Miller (2007) conducted a corpus search that revealed many attested occurrences from wide variety of sources.

***For*-adverbials** One of the advantages of event semantics is that it allows for elegant treatments of duration, tense and aspect (Parsons 1990) through, for instance and among other tools, the introduction of a function τ sending an event to its runtime (when such an object exists).[2] In particular, *for*-adverbials can be accounted for as in example (19), by specifying the runtime of the event in question:

(19) a. For two hours, Mary laughed.
b. $\exists e.\ laugh(e) \wedge \mathtt{Ag}(e) = Mary \wedge 2h(\tau(e))$

For-adverbials are perfectly acceptable with negative sentences as well, which Przepiórkowski (1999) takes as evidence that these sentences — as positive ones do — state the existence of some event too. Sentence (20-a), for example, is natural and is interpreted as stating that there is a two hours long period of time during which Mary did not laugh. Once again, in these cases the SAN does not provide any event the adverbial could specify the runtime of and must resort to more complex techniques (Krifka 1989; Champollion 2015):

(20) a. For two hours, Mary did not laugh.
b. $(\neg\exists e.\ laugh(e) \wedge \mathtt{Ag}(e) = Mary) \wedge 2h(\tau(???))$

These reasons seem sufficient to justify the search for an alternative to the SAN. More precisely, this paper argues that negative sentences introduce events, so that negation can be defined on the event domain, and that these so called 'negative events' are available for causal statements, perception reports and adverbial modification. Before turning to this proposal, the next section reviews some relevant work on negation in event semantics.

3. Non-standard negation in event semantics

3.1. Krifka's fusion-based negation

As mentioned earlier, Krifka (1989) introduces a term for negation that turns a set of events into another set of events, and this move was motivated by the analysis of *for*-adverbials.

In a first step, Krifka defines a 'maximal event' as an event that is the sum of all events whose runtime is included in a given period of time.[3] This corresponds to a **MXE** predicate satisfying:

(21) $\forall e.\ \mathbf{MXE}(e) \leftrightarrow (\exists t.\ e = \mathbf{FU_E}(\lambda e.\ \tau(e) \subseteq_T t))$

Because such a maximal event e contains *all* events at t, if, for instance, there is no event of Mary laughing included in e, then it logically follows that Mary did not laugh at any moment during t. Negation of a predicate P can thus be expressed by stating that the maximal event at a given time does not contain any event satisfying P:

(22) $[\![\text{not}]\!]_K = \lambda Pe.\ \mathbf{MXE}(e) \wedge \neg\exists e'.\ (P(e') \wedge e' \subseteq_E e)$

While Krifka shows that this account of negation correctly predicts the two possible interpreta-

[2] In this article, tense and aspect are neglected for the sake of clarity.

[3] Krifka works in a *mereological* setting (Champollion & Krifka 2016), in which an event can be either *atomic* or a *sum* of other events. The symbol $\mathbf{FU_E}$ used in equation (21) refers to a function that returns the sum of all events satisfying the predicate given as argument, which is an event itself as in such a mereological setting, summation of events is defined as a function from sets of events to events.

tions of sentences such as (23), by having the temporal modifier *for two hours* (whose interpretation mainly amounts to $\lambda Pe.\ P(e) \wedge 2h(\tau(e))$) scoping under or over the negation (leading to the paraphrases in (23-a) and (23-b) respectively), it suffers from serious limitations.

(23) Mary did not laugh for two hours.
   a. There is no period of two hours during which she laughed. ($\neg > \exists$)
   b. There is a certain period of two hours during which she did not laugh. ($\exists > \neg$)

First, as shown in (24), negating twice a telic predicate P leads to unnatural interpretations. If $[\![\text{not}]\!]_K([\![\text{not}]\!]_K P)$ is true of an event e, then for every sub-period of time t' of the runtime of e there exists an event (e'') satisfying P and whose runtime is included in t'; this wrongly predicts that if yesterday Mary did not *not* reach the top of the mountain, then she reached it at every single hour, and every single minute, etc.

(24) $[\![\text{not}]\!]_K([\![\text{not}]\!]_K P)$
   a. $= \lambda e.\ \mathbf{MXE}(e) \wedge \neg\exists e'.\ (\mathbf{MXE}(e') \wedge \neg\exists e''.\ (P(e'') \wedge e'' \subseteq_E e') \wedge e' \subseteq_E e)$
   b. $= \lambda e.\ \mathbf{MXE}(e) \wedge \forall e'.\ (\mathbf{MXE}(e') \wedge e' \subseteq_E e \rightarrow \exists e''.\ (P(e'') \wedge e'' \subseteq_E e'))$

More importantly, Krifka's account of negation does not really introduce the kind of negative events suitable for causal statements, perception reports or adverbial modification. A maximal event e is the sum of everything that happened during some period of time t; e therefore represents that sum and could possibly be used to represent — in negative — the sum of everything that did not happen during t, but it could not be used to represent any single event that did or did not occur during t. If Mary did not laugh yesterday and did not ride her bike during the same time, the same maximal event is invoked in Krifka's account. In particular, if Mary is sad because she did not ride her bike or if John saw her not laugh, it is not the maximal event mentioned that causes Mary's sadness nor that was seen by John.

3.2. Higginbotham's negative naked infinitives

Higginbotham (1983) suggests that the negation in a sentence such as (17-a) (repeated below as (25-a)) cannot simply lexicalise a logical negation ($\neg$), whatever its scope may be; in particular, (25-a) does not merely mean that I did not see Mary leave, nor that I saw something that did not involve Mary leaving.[4] Because of the similarity between (25-a) and (25-b), Higginbotham postulates without providing any further precision that in some cases, negation combines with a predicate P to form a 'not-P' event predicate.

(25) a. I saw Mary not leave.
   b. I saw Mary stay.

In later work (Higginbotham 2000), he mentions that negative events would be useful in analysing not only perceptual reports as in (25-a) but also temporal modification as in (23) above, causal statement as in (26-a) and negative noun-phrases as in (26-b).

[4]Indeed, the truth conditions of these candidates are not right. If I was alone at home playing the piano, for instance, then it is true that I did not see Mary leave, but it is false that I saw Mary not leave. Similarly, if, while playing the piano, I saw my cats chasing each other in the leaving room, then it is true that I saw something that did not involve Mary leaving, but it is still false that I saw Mary leave.

(26) a. I kept the child awake by not turning out the light.
b. Bill's non-departure

He then precises that the 'not-P' predicate, resulting from the interaction of negation and P and noted $\overline{P}$, should obey the following axiom:

(27) $\forall t.\ (\neg\exists e.\ (\tau(e) \subseteq_T t \wedge P(e)) \rightarrow (\exists e'.\ \overline{P}(e') \wedge \tau(e') = t)$

This axiom means that when there is no event satisfying P with a runtime included in t, then there is an event satisfying $\overline{P}$ with runtime exactly t. Therefore, if I did not turn out the light and if Mary did not laugh, the axiom provides the existence of events that might be suitable for the causal relation in (26-a) and the temporal predicate of (23) respectively. However, the meaning of the negation is not explicitly provided and is only supposed to be able to produce $\overline{P}$ from P. Furthermore, because the implication is only left to right (in place of an equivalence), axiom (27) makes the predicate $\overline{P}$ not very informative. Indeed, as is, the existence of a $\overline{P}$ event does not entail anything about the (non-)existence of P events. As a result, the Mary-not-leaving event that I saw if sentence (25-a) is true could coexist with an event of Mary leaving, or in other words, I could have seen Mary not leave even though she left (at the same time t). We see that in this account, as it stands, negation does not get a satisfying logic. In the remainder of this section, I explain why Higginbotham's approach has not (and probably cannot) be immediately and satisfyingly supplemented.

As mentioned above, Higginbotham explicitly refers to the similarity between a not-staying and a leaving. *Stay* and *leave* lexicalise a pair of 'antonymic predicates'; other examples are *eat*/*fast*, *forget*/*remember* or *succeed*/*fail*. The idea behind Higginbotham's negation is that it is able to switch from one predicate of the pair to the other.[5] Following this analysis, the event I saw if sentence (25-a) is true is an e such that $\overline{leave}(e) \wedge \mathtt{Ag}(e) = Mary$ (or equivalently with $stay$ instead of $\overline{leave}$). Now, a not-leaving by Mary does not entail the non-existence of all leavings altogether, only those by Mary. So strengthening Higginbotham's axiom to a biconditional would lead to a wrong, overly strong prediction.

Still, one could hope to improve axiom (27) in order to predict that a not-leaving of Mary is incompatible with her leavings. The main difficulty one faces when trying to solve this problem is that the events that are precluded by a $\overline{P}$ event e are not characterised only by P but also by some other properties of e. A non-leaving by agent x at time t seems to preclude all leavings by x with a runtime included in t, but for a not-eating, the 'theme' (what is not eaten) also has to be taken into account. If, for any P, there exists a definite set of dimensions (time, agent, theme, etc.) D_P such that a P event e is logically incompatible with any $\overline{P}$ event e' with the dimensions in D_P assigned similarly (what is noted below as '$B_P(e) = B_P(e')$'), then axiom (28) would be a good start:

(28) $\forall X.\ \neg\exists e.\ P(e) \wedge B_P(e) = X \leftrightarrow \exists e'.\ \overline{P}(e') \wedge B_P(e') = X$

However, this formula does not handle the time dimension correctly: a non-leaving by Mary with runtime t does not only preclude the leavings by Mary with runtime *equal* to t, but all those with runtime *included* in t.

In conclusion, while this idea of antonymic predicates is intuitively appealing, it is not clear

[5] Few verbs in English have an antonymic counterpart, but this simply means that the corresponding antonymic predicates are not lexicalised, and only expressible through a negated verb.

how it could be properly formalised. However, the next section presents a proposal that is relatively close in spirit to the work of Higginbotham; only, instead of interpreting negation as turning a predicate P into the not-P *predicate* $\overline{P}$, it will be interpreted as turning P into the not-P *event* $Neg(P)$. This will allow one to consider a stronger and more informative axiom for negation, yielding a simple and coherent logic.

4. Defining negative events

4.1. Actuality of events

So far in this article, all the events considered were *actual*, in the sense that the *existence* of an event in the model (i.e., its inclusion in the event domain of the model) represented the *occurrence* of a corresponding event in the world described by the model. However, in order to account for negation, I propose to consider models including non-actual events, that is, entities representing events that have not and will never occur in the world.

Actuality and non-actuality of events are not particularly new concepts: in event semantics with possible worlds, one needs a way to distinguish between the events occurring in such or such worlds. For instance, if each possible world has its own event domain, *Maybe it is raining* can be translated as stating the existence of a raining event in some but not all accessible doxastic worlds. In such a setting, actuality in a given world can be seen as membership in the event-domain of this world. Because the analysis argued for in this paper does not require possible world semantics, I will simply postulate the existence of an $actual$ predicate (which could be a primitive or, alternatively, be defined in terms of possible worlds semantics, for instance) and consider only one event domain.

With non-actual events in our models, sentence (29-a) cannot be taken as only stating the existence of a raining event, because this event could be non-actual; instead, it states the existence of an *actual* raining event.

(29) a. It is raining.
b. $\exists e.\ actual(e) \wedge rain(e)$

Similarly, sentence (30-a) does not necessarily state the non-existence of *all* raining events, but only of actual ones.

(30) a. It is not raining.
b. $\neg\exists e.\ actual(e) \wedge rain(e)$

The idea behind non-actual events is that for two predicates P and Q, if no P nor any Q events occurred, the interpretations of P and Q in the model can still be non-empty (because of possible non-actual events), and thus different; while in a semantics without non-actual events, both interpretations would be the empty set, which mean the two predicates would be indistinguishable.[6]

[6] In other words, non-actual events are a way to fight a form of extensionality.

4.2. The Neg function

At the core of the present proposal is a function $Neg : \langle\langle v, t\rangle, v\rangle$, sending a set of events P to some event $Neg(P)$, intuitively representing *the* not-P event.[7] The interpretation of $Neg(P)$ events is governed by the following axiom:[8]

(31) Axiom of negation: $\forall P.\ actual(Neg(P)) \Leftrightarrow \neg\exists e.\ actual(e) \wedge P(e)$

The Neg function can serve as a basis to define a negation working not on the propositional domain, but on sets of events, thus resolving (for negation) the mismatch at the source of the EQP.[9] Indeed, sentence (30-a) (repeated below as (32-a)) can now be translated as (32-b). Because of the axiom of negation, this formula is logically equivalent to the one obtained with the SAN. What is new, however, is the availability of the not-rain event e, which, in contrast to the maximal events used by Krifka (1989), is specific to the negated predicate.

(32) a. It is not raining.
b. $\exists e.\ actual(e) \wedge e = Neg(\lambda e'.\ rain(e))$

4.3. Logic

In this section, I review a few theorems stemming for the axiom of negation defined above.

Law of excluded middle and law of non-contradiction For any event predicate P, either there exists an actual P-event, or $Neg(P)$ is actual, and not both:

(33) $(\exists e.\ actual(e) \wedge P(e)) \oplus actual(Neg(P))$

(using exclusive disjunction $\oplus$). With, for instance, P referring to the set of (past) leavings by Mary, this corresponds to sentence (34-a-i) and its negation (34-b-i) being contradictory:

(34) a. (i) Mary left.
(ii) $\exists e.\ actual(e) \wedge leave(e) \wedge \mathtt{Ag}(e) = Mary$
b. (i) Mary did not leave.
(ii) $actual(Neg(\lambda e.\ leave(e) \wedge \mathtt{Ag}(e) = Mary))$

Theorem (33) is immediate from the axiom of negation.

Double negation With truth of an event predicate P being the existence of an actual event satisfying P, double negation always preserves truth:

[7] The interpretation of Neg in a model with event domain D_v and truth domain D_t is a function from the set ${D_t}^{D_v}$ to the much smaller (as soon as at least two truth values are considered) D_v. Hence, this function is either non-injective or partial. The latter view seems preferred, as linguistic utterances arguably only refer to a small number of the $|D_t|^{|D_v|}$ possible sets of events. Indeed, I take the set of possible sentences to be countably infinite while if the set of all events is also countably infinite, then the set of all sets of events is not countable.

[8] In case Neg is a partial function (see note 7), this axiom is restricted to the Ps such that $Neg(P)$ is defined.

[9] Describing a syntax-semantics interface with negative events is out of the scope of the present paper — it is a topic investigated by Bernard (2017); Bernard & Champollion (forthcoming) —; nevertheless, here is a possible simple lexical entry for sentential negation: $[\![\text{not}]\!] \equiv \lambda Pe.\ e = Neg(P)$.

(35) $actual(Neg(\lambda e.\ e = Neg(\lambda e'.\ P(e')))) \Leftrightarrow \exists e.\ P(e) \wedge actual(e)$

For instance, sentence (34-a-i) above and its double negation (36-a) are logically equivalent.

(36) a. Mary did not *not* leave.
b. $actual(Neg(\lambda e.\ e = Neg(\lambda e'.\ leave(e') \wedge \texttt{Ag}(e') = Mary)))$

A proof of theorem (35) is given here:

$$\begin{aligned} & actual(Neg(\lambda e.\ e = Neg(\lambda e'.\ P(e')))) \\ & \Leftrightarrow \forall e.\ e = Neg(\lambda e'.\ P(e')) \rightarrow \neg actual(e) \\ & \Leftrightarrow \neg actual(Neg(\lambda e'.\ P(e'))) \\ & \Leftrightarrow \exists e'.\ P(e') \wedge actual(e') \end{aligned}$$

Downward entailment For any two event predicates P and Q, the negation of one of them entails the negation of their conjunction:

(37) $actual(Neg(\lambda e.\ P(e))) \Rightarrow actual(Neg(\lambda e.\ P(e) \wedge Q(e)))$

For instance, sentence (34-b-i) above entails sentence (38-a).

(38) a. Mary did not leave at 10 PM.
b. $actual(Neg(\lambda e.\ leave(e) \wedge \texttt{Ag}(e) = Mary \wedge 10\_PM(\tau(e))))$

A proof of theorem (37) is given here:

$$\begin{aligned} & actual(Neg(\lambda e.\ P(e))) \\ & \Rightarrow \forall e.\ P(e) \rightarrow \neg actual(e) \\ & \Rightarrow \forall e.\ P(e) \wedge Q(e) \rightarrow \neg actual(e) \\ & \Rightarrow actual(Neg(\lambda e.\ P(e) \wedge Q(e))) \end{aligned}$$

5. Discussion

5.1. Treating positive and negative constructions homogeneously

Causal statements With the Neg function, one is able to access negative events that fit naturally in the analysis of causal statements. I propose formula (39-b) as a logical representation of sentence (15-a) (repeated below as (39-a)). The use of negation in the description of the cause is straightforwardly reflected as a use of Neg in the construction of the event representing that cause:

(39) a. Mary is tired because she did not sleep (well).
b. $\exists e_1.\ actual(e_1) \wedge tired(e_1) \wedge \texttt{Exp}(e_1) = Mary \wedge \exists e_2.\ actual(e_2) \wedge e_2 = Neg(\lambda e.\ sleep(e) \wedge \texttt{Ag}(e) = Mary) \wedge cause(e_1, e_2)$

The analysis is similar for the example used by Higginbotham (2000):

(40) a. I kept the child awake by not turning out the light.

b. $\exists e_1.\ actual(e_1) \wedge keep\_awake(e_1) \wedge \texttt{Ag}(e_1) = I \wedge \texttt{Th}(e_1) = the\_child \wedge \exists e_2.\ actual(e_2) \wedge Neg(\lambda e.\ turn\_out(e) \wedge \texttt{Ag}(e) = I \wedge \texttt{Th}(e) = the\_light) \wedge cause(e_1, e_2)$

Perception reports In the same vein — if one allows these negative events to be observed by individuals — a perception report with a negated naked infinitive such as (17-a) (repeated below as (41-a)) can be analysed in a way similar to one not involving negation, as proposed by Higginbotham (1983):

(41) a. I saw Mary not leave.
b. $\exists e_1.\ actual(e_1) \wedge e_1 = Neg(\lambda e.\ leave(e) \wedge \texttt{Ag}(e) = Mary) \wedge \exists e_2.\ actual(e_2) \wedge see(e_2) \wedge \texttt{Ag}(e_2) = I \wedge \texttt{Th}(e_2) = e_1$

Intersective adverbs Thanks to Neg, cases of intersective adverbs as in sentence (18-b-i) (repeated below as (42-a)) do not pose more problems with VP negation than in a construction without negation:

(42) a. Unexpectedly, Mary did not leave. $\Rightarrow$ Mary did not leave.
b. $\exists e.\ actual(e) \wedge unexpected(e) \wedge e = Neg(\lambda e'.\ leave(e') \wedge \texttt{Ag}(e') = Mary)$
$\Rightarrow \exists e.\ actual(e) \wedge e = Neg(\lambda e'.\ leave(e') \wedge \texttt{Ag}(e') = Mary)$

***For*-adverbials** Concerning the analysis of *for*-adverbials, the current proposal and the SAN face similar difficulties. Even if *Mary did not laugh* in sentence (20-a) (repeated below as (43)) introduced an event e equal to $Neg(\lambda e'.\ laugh(Mary))$, e would not be fit for temporal modification. Indeed, such $Neg(\lambda e'.\ laugh(Mary))$ is unique and whatever its runtime may be, its actuality would entail the non-actuality of all laughing events by Mary, independently of their runtime.

(43) For two hours, Mary did not laugh.

A intuitive direction would be to suppose that *for two hours* is able to inject a time restriction inside the scope of Neg, in order to generate a formula akin to:

(44) $\exists t.\ 2h(t) \wedge \exists e.\ actual(e) \wedge e = Neg(\lambda e'.\ laugh(e') \wedge \texttt{Ag}(e') = Mary \wedge \tau(e') \subseteq t)$

This formula gets the correct semantics. Unfortunately, it is doubtful that one can compositionally derive at the same time the correct formulas for the negative cases, for which the time restriction is of the form '$\tau(e') \subseteq t$' ('there is no P-event with runtime *included* in t'), and for the positive cases, for which the time restriction is of the form '$\tau(e) = t$' ('there is a P event with runtime *equal* to t'):

(45) a. For two hours, Mary laughed.
b. $\exists t.\ 2h(t) \wedge \exists e.\ actual(e) \wedge laugh(e) \wedge \texttt{Ag}(e) = Mary \wedge \tau(e) = t$

However, only a couple of minor changes are required in order to interpret *for*-adverbials scoping over a negation as directly modifying the corresponding negative event, as advocated by Przepiórkowski (1999). The first change consists in defining the runtime of negative events, for instance with:

(46) $\tau(Neg(P)) = \bigcup_{e \text{ s.t. } P(e)} \tau(e)$ (when τ is defined for all e in P)

The second one consists in introducing a mechanism using this runtime to coherently constrain which of the events are negated (i.e., precluded by the negative event). A possible solution is to define a lexical entry for negation that does not directly negate the predicate given as argument, but only a subset determined by the runtime of the negative event itself (e.g., $[\![\text{not}]\!] \equiv \lambda Pe.\ e = Neg(\lambda e'.\ P(e') \wedge \tau(e') \subseteq \tau(e))$ using a kind of 'fixed point' notation, or equivalently with an existentially quantified implicit time variable: $[\![\text{not}]\!] \equiv \lambda Pe.\ \exists t.\ e = Neg(\lambda e'.\ P(e') \wedge \tau(e') \subseteq t)$). Then, sentence (43) can be translated as:

(47) $\exists e.\ actual(e) \wedge 2h(\tau(e)) \wedge e = Neg(\lambda e'.\ laugh(e') \wedge \mathtt{Ag}(e') = Mary \wedge \tau(e') \subseteq \tau(e))$

which, as expected, is true iff there exists a two hours period during which no laughing by Mary occurred.[10] Please remark that these modifications do not interfere with the other analyses presented in this article.

5.2. Negative views on negative events

While the existence and availability of negative events have been argued for in the literature (Higginbotham 1983, 2000; de Swart 1996; Peterson 1997; de Swart & Molendijk 1999; Przepiórkowski 1999, among others) many arguments against them have been made.

According to Asher (1993, 2000), a negative NP such as *the nonarrival of the train* does not denote an event, as it is not compatible with *perfect nominal containers* (Vendler 1967):[11]

(48) *The nonarrival of the train occurred at 10 A.M. (lasted many hours; took place at the station in Victoria).

Here, the terminology seems crucial. The word *events* is sometimes used as a cover term for all the entities of a logical language (and their model-theoretic counterparts) that serve as implicit arguments of verbs, extending the Davidsonian analysis beyond action verbs — possibly to the whole set of verbs and sometimes even to other kinds of predicates (see for instance Peterson 1997). This use of the term gives emphasis to the logical representations of utterances, in which all these entities play the same role — hence a unique term —, but is not incompatible with further sorting of the event domain into 'proper events', states, etc., according to other considerations. On the opposite side, Asher (1993, 2000) aims at defining a *natural language metaphysics* and thus reserves 'event' for discourse entities of a specific kind.[12]

While Asher denies the existence of negative *events*, he takes *Mary didn't swim* and *Mary*

[10] Here, the time restriction is handled explicitly in the logical language. The burden could be put on the semantic interpretation instead, using a function $Neg' : \langle\langle v, t\rangle, \langle v, t\rangle\rangle$ sending a set of events to another set of events along with an alternative axiom of negation:

(i) $\exists e.\ actual(e) \wedge Neg'(P)(e) \wedge \tau(e) = t \Leftrightarrow \neg\exists e'.\ actual(e') \wedge P(e') \wedge \tau(e') \subseteq t$

[11] Following Higginbotham (2000) and according to a principle of economy, I believe that the same tools used to express the semantics of negative naked infinitives could be used to express the one of negative NPs. For instance, *the nonarrival of the train* could be expressed with Neg as $Neg(\lambda e.\ [\![\text{arrival of the train}]\!](e))$.

[12] The other kinds of discourse entities studied by Asher are states, propositions and facts.

wasn't at home in the following sentences to refer to negative *states*:

(49) a. After Mary didn't swim, she went home.
b. While Mary wasn't at home, John cleaned up the house.

Events and states are generally grouped together as 'eventualities', and Przepiórkowski (1999) mainly uses that term (even though, following de Swart & Molendijk 1999, he claims that at least some negated clauses refer to events, not states). In the present article, 'event' has been used in the technical/logical sense, which means that no claim has been made concerning whether the images of Neg are truly events, states, or some other kinds of discourse entities. These distinctions are not relevant for the examples discussed here; rather, what is relevant is whether one can obtain semantic representations with satisfying entailment properties for a wide array of sentences by postulating that negation yields first-order entities (in the logical sense) in an event-based semantics.

Some authors, however, argue against any kind of negative eventualities, and instead, for what I will call the 'positive events under negative descriptions' view (henceforth 'POUND view'). For instance, Miller (2007) claims that negation in perception reports amounts to a usual boolean negation and that *John saw Mary not leave* gets the same semantics as *John saw some eventuality that was not Mary leaving*; in other words, 'the sentence turns out to be true whatever John saw as long as it was not a case of Mary leaving' (p.299). The reasoning is that if *John saw Mary not leave* is true, then it seems the case that John saw something, and that this something might have been Mary drinking a glass of Chardonnay in the living room, eating some Camembert in the kitchen, etc., in short, any kind of usual eventuality that turns out to be described negatively. A similar analysis is defended by Varzi (2006).

The first issue with this view is that it does not readily explain why if John saw Mary not leave (and John does not suffer from hallucination), then Mary did not leave. Some pragmatic process can be invoked, but this idea is formalised neither by Miller (2007) nor Varzi (2006), while the same effect is directly achieved in the semantics presented here.

Varzi (2006) takes the POUND view quite far and claims, for the same reasons, that there is no failure nor omission eventuality. A consequence of this is that in case Al did not even try to turn off the gas, 'strictly speaking [sentence (50)] is false, or at least not true. It is not true because the subject term, "Al's failure to turn off the gas" (unlike the term "Beth's turning on the light"), has no referent' (p.144). I believe this is a pretty bad consequence, all the more that this line of reasoning can be applied similarly to forgetting, fasting, or even staying eventualities. Obviously, this might be fixed with the help of pragmatics, but I am sceptical about the benefit of trading a coherent and working semantics for an unstable system hoping for repair.

(50) Al's failure to turn off the gas caused an explosion.

The POUND view seems to originate from the idea that it is hard to imagine what a truly negative eventuality is.[13] Such argumentation is dubious. First, the fact that most people fail to mentally picture the nature of photons (behaving like particles in some conditions, like waves in others, but more generally like an excitation of the photon field) does not mean that there is no such thing as a photon. More importantly, as convincingly argued for instance by Asher (1993), natural language metaphysics does not need to equal 'true' metaphysics. In other words, there is no reason to postulate an isomorphism between the entities used to represent the meaning of

[13]This argument is also given by Asher (1993, 2000) against negative events specifically.

linguistic utterances and what is taken to exist in the world. Maybe there is no Mary-not-leave eventuality in the world, but people speak as if it was so, and as long as these entities do not introduce any inconsistency, there is no reason to refrain from using negative eventualities in semantic modelling.

Nevertheless, it is interesting to note that the POUND view can be accommodated in a purely semantic fashion by using a $Neg'' : \langle\langle v, t\rangle, \langle v, t\rangle\rangle$ function sending a set of eventualities (for instance the leavings by Mary) to the sets of its precluding eventualities (i.e., all eventualities the occurrence of which precludes the occurrences of all of her leavings, such as Mary drinking wine in the living room or eating cheese in the kitchen), along with the following axiom of negation:

(51) $\exists e.\ actual(e) \wedge Neg''(P, e) \Leftrightarrow \neg\exists e.\ actual(e) \wedge P(e)$

In any case, the same way as I believe in the relevance of failing, forgetting, fasting, or omission eventualities for semantics, I believe that the sort of abstract negative eventualities handled with Neg are relevant too.

6. *Conclusion*

In this article, several problems faced by event semantics have been discussed. I have argued that the culprit was the standard analysis of negation, according to which a negated sentence expresses the non-existence of events satisfying a given predicate, instead of the existence of some event — as for a positive one.

After having reviewed a couple of alternatives, I have given a formal definition of negative event(ualitie)s. At the core of this definition lies the function $Neg : \langle\langle v, t\rangle, v\rangle$, that sends a set of events P to what is interpreted as the not-P event.

I have shown that the logic induced by the axiom of negation in (31) makes Neg suitable to express the semantics of natural language negation. In particular, we have seen how the negative events thus defined make it possible to analyse perception reports, causal statements, *for*-adverbials and other cases of adverbial modification homogeneously, independently of the presence of a negation in their argument(s). The solution proposed only adds a little complexity to the logical language and model, but simplifies greatly the analysis of negative constructions in a fashion that preserves (and extends in coverage) the inferential properties of event semantics that made it appealing in the first place.

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