

Negative events in compositional semantics*

Timothée Bernard
Université Paris Diderot

Lucas Champollion
New York University

Abstract Negative events have been used in analyses of various natural language phenomena such as negative perception reports and negative causation, but their conceptual and logical foundations remain ill-understood. We propose that linguistic negation denotes a function Neg , which sends any set of events P to a set $Neg(P)$ that contains all events which preclude every event in P from being actual. An axiom ensures that any event in $Neg(P)$ is actual if and only if no event in P is. This allows us to construe the events in $Neg(P)$ as negative, “anti- P ”, events. We present a syntax-semantics interface that uses continuations to resolve scope mismatches between subject and verb phrase negation, and a fragment of English that accounts for the interaction of negation, the perception verb *see*, finite and nonfinite perception reports, and quantified subjects, as well as negative causation.

Keywords: negative events, negation, event semantics, syntax-semantics interface, compositional semantics, continuations, perception reports, negative causation

1 Introduction

Events have featured in semantic analyses of a wide variety of natural language phenomena such as perception reports, causation, and nominalizations (Parsons 1990 and references therein).

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|-----|----|--|--------------------------|
| (1) | a. | I saw Mary leave. | <i>Perception report</i> |
| | b. | I put the child to sleep by turning off the light. | <i>Causation</i> |
| | c. | Mary’s departure made John sad. | <i>Nominalization</i> |

In compositional frameworks, event semantics is often deployed alongside analyses of scope-taking expressions in terms of their counterparts in propositional or predicate logic. For example, truth-functional linguistic negation (*not*) is often analysed in terms of logical negation (\neg) (Horn 1989).

An analysis of linguistic negation in terms of logical negation is not by itself

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incompatible with event semantics. For example, Champollion (2011, 2015) and de Groote & Winter (2015) analyze (2a) as in (2b), disregarding tense.

- (2) a. John did not laugh.
 b. $\neg\exists e[\textit{laugh}(e) \wedge \textit{ag}(e) = \textit{John}]$

However, this approach is not equally compatible with all applications of event semantics. In particular, analyses of perception reports do not mesh well with analyses of linguistic negation in terms of logical negation (Higginbotham 1983, 2000). For example, sentence (3a) cannot be represented as formula (4a), because (3a) entails that the speaker saw Mary stay while (4a) is true even if Mary left, as long as the speaker did not see her leave. If the formula in (4a) captures the truth conditions of any sentence, it would be (4b). Nor can (3a) be represented as (5a), as that formula is trivially verified by almost any event.

- (3) a. I saw Mary not leave. (Higginbotham 1983)
 (4) a. $\neg\exists e. [\textit{leave}(e) \wedge \textit{ag}(e) = \textit{Mary} \wedge e \in \llbracket\textit{I saw}\rrbracket]$
 b. It's not the case that I saw Mary leave.
 (5) a. $\exists e. \neg[\textit{leave}(e) \wedge \textit{ag}(e) = \textit{Mary} \wedge e \in \llbracket\textit{I saw}\rrbracket]$

In this paper, we take an alternative approach and analyze negative perception reports like (3a) in terms of negative events. Some negative events are fairly easy to think about in intuitive terms. For example, the negative event in (3a) can be thought of as the event of Mary's staying. Other negative events, however, cannot be paraphrased so easily, as we see for example with (2a). A non-laughing event is not just any event that is not a laughing; rather, it is an event that prevents laughing from taking place.

Negative events have figured in analyses of a number of phenomena beyond perception reports. These include reports of negative causation, such as (6), and anaphoric reference as in (7) (Higginbotham 1983, 2000); and modification of negated clauses as in (8) (Przepiórkowski 1999). A related concept appears in Krifka's (1989) analysis of temporal modification of negated verb phrases, as in (9). See Casati & Varzi (2015: Sect. 2.5) for other uses of negative events in the semantic and philosophical literature.

- (6) I kept the child awake by not turning off the light.
 (7) $[\textit{Mary did not leave}]_i. \{ \textit{This}_i / \textit{Mary's non-departure} \}$ made John happy.
 (8) Twice, Mary did not go to Paris.
 (9) For two hours, Mary did not laugh.

In this paper, we show how negative events can be integrated into standard

model-theoretic semantics for a suitable fragment of natural language. Following Higginbotham (1983), we focus on ordinary and quantified perception reports, more specifically on nonfinite and finite complements on the verb *see*, such as (3a) and (10).

(10) I saw (that) Mary did not leave.

The structure of this paper is as follows. In Section 2, we state our fundamental assumptions concerning the nature of negative events, their relation to ordinary (non-negative) events, and the way they enter the compositional semantics. In Section 3, we propose an axiom that constrains the behavior of our negative events. Since previous work has not shown how negative events are introduced in a compositional fashion, Section 4 discusses various strategies for compositionally deriving the interpretation of linguistic utterances involving verb phrase negation. This leads us to Section 5, in which we develop a fragment of English for simple positive and negative statements, perception reports with (non)finite complements, as well as reports of negative causation. In Section 6, we discuss previous work formalizing non-standard treatments of negation in event semantics. We conclude in Section 7.

2 Fundamental assumptions

We begin by stating our fundamental assumptions concerning the nature of negative events, their relation to ordinary (non-negative) events, and the way they enter the compositional semantics.

One might conceive negative events as intrinsically negative, independently of the way they are described, or as negative only under some descriptions but not others. On the first view, Mary's non-departure would be an intrinsically negative event; on the second view, it is negative under the description "not leave" but not under the description "stay". While our formalization is compatible with the first view, we follow the philosophical lead of Bentham (1789: ch. 7, §10) and Varzi (2006) and assume that events are not negative intrinsically but only under certain descriptions (namely those that involve linguistic negation).

Our theory rests on the central assumption that events may be actual or non-actual. Intuitively, actual events are events that are the case, while non-actual events are conceivable events that are not the case. The distinction between actual and non-actual entities is not specific to events. Individuals too can be actual, such as Margaret Thatcher or Barack Obama, or non-actual, such as Mary Poppins or Santa Claus. In the context of possible world semantics, one may think of actual events as events that exist at the actual world, and of non-actual events as those that do not; however, nothing rests on this assumption and one may as well take actuality to be an unanalyzed property of events.

Distinguishing between actual and non-actual events allows us to formalize the notion that two events may *preclude* each other. By this we mean two events that cannot co-occur. For instance, Mary's departure and her non-departure preclude each other. If she left, we will say that her departure is actual and her non-departure is non-actual; if she stayed, we will say that it is the other way around.

At the heart of our proposal is the function *Neg*. We assume that this function sends every set of events P to a set of events $Neg(P)$, the set of its precluders. Specifically, $Neg(P)$ contains all and only those events which preclude every event in P . For a predicate or set P , we will refer to events in P as P -events and to events in $Neg(P)$ as anti- P events. The intuitive meaning of this function is the following. Let P be a set of events, such as the set of all of Mary's departures (actual or otherwise) on a specific occasion. If Mary left, then one of these events will be actual; if she stayed, none of these will be. Also, an event will belong to $Neg(P)$ just in case it precludes Mary's departure. Since Mary cannot have left and stayed at the same time, this set will include all of her stayings. If Mary left, none of these events will be actual; if she stayed, at least one of them will be actual. (A variant of our system, presented by Bernard (to appear), assumes that $Neg(P)$ sends any P to a single event; in terms of the present proposal, this corresponds to assuming that $Neg(P)$ is a singleton set. This assumption does not affect the main aspects of our system but seems unnecessary, so we drop it here.)

For some instances of P one may identify their precluders with familiar events, in line with the Bentham and Varzi view. For example, it is fairly intuitive to take the set of Mary's departures to have the set of her stayings as its precluders. For other cases, such as the set of John's laughings or the set of all events that take place on a Tuesday, this will not be so easy. What does it mean to be an anti-laughing or anti-Tuesday event? We refrain from giving an answer here. Our strategy is to generalize *Neg* so that it applies to any set whatsoever. The precluders will in some cases be highly abstract entities, similarly to imaginary numbers in mathematics. In other cases, they will be concrete entities which can be perceived, can be causes and effects, and so on. We do not assume that a given precluder can necessarily be described by any non-negated predicate. The addition of precluders to the model is a purely technical move with no metaphysical or ontological claims attached to it.

3 An axiom for negative events

Any theory of negation should make predictions about entailment and contradiction with respect to sentences involving it. When linguistic negation is analyzed in terms of logical negation, these predictions follow from the well-known behavior of logical negation in classical systems of propositional and predicate logic. Here, however, we analyze linguistic negation in terms of precluding events and the *Neg* function

rather than in terms of logical negation. We therefore provide an axiom for the *Neg* function and show that it gives rise to classical behavior. Our axiom is inspired by a proposal in Higginbotham (2000), which we discuss in Section 6. Here it is:

- (11) **Axiom of negation**
 $[\exists e \in \text{Neg}(P). \text{actual}(e)] \leftrightarrow [\forall e' \in P. \neg \text{actual}(e')]$

This axiom states two things. First, read from left to right, it states that if there is an actual $\text{Neg}(P)$ event, then there is no actual P event. For example, let P be the set of all of Mary's departures (actual or not) and $\text{Neg}(P)$ the set of all her stayings (actual or not), as above. Then the left-to-right direction of the axiom states that if Mary actually stayed, then none of her departures is actual; it cannot be the case that she both stayed and left. Second, read from right to left, the axiom states that if there is no actual P event, then there is an actual $\text{Neg}(P)$ event; or to put it differently, if no event in $\text{Neg}(P)$ is actual, then one of the events in P is actual. In Mary's case, this means that if she did not stay, she must have left; it cannot be the case that she neither stayed nor left. We may say that two events co-occur if and only if they are both actual; then this axiom states that P events and $\text{Neg}(P)$ events do not co-occur, and that in all circumstances, at least one of them is actual.

Because we have non-actual events in our ontology, merely existentially quantifying over some event does not ensure that this event is actual. For example, a formula such as $\exists e. \text{rain}(e)$ does not state that it is raining, only that there is a raining event that may or may not be actual. In terms of possible-world semantics, existence in this formal sense corresponds to existence at some possible world which may or may not be the actual world, while actuality corresponds to occurrence in the actual world.

Under this conception of events, ordinary sentences describe actual and not merely possible events. To capture this fact, we translate them with an occurrence of the predicate *actual*, as in the following example:

- (12) a. It is raining.
 b. $\exists e. \text{actual}(e) \wedge \text{rain}(e)$

To translate negative statements, we use the *Neg* function. Sentence (13a), for instance, can be translated as (13b), as opposed to (13c). Here and below, we equate sets with their characteristic functions; thus we make no difference between $\{e \mid \text{rain}(e)\}$ and $\lambda e. \text{rain}(e)$.

- (13) a. It is not raining.
 b. $\exists e. \text{actual}(e) \wedge e \in \text{Neg}(\lambda e'. \text{rain}(e'))$
 c. $\neg \exists e. \text{actual}(e) \wedge \text{rain}(e)$

Formula (13b) states that some anti-rain event is actual. Because of the axiom of negation, this is equivalent to asserting that no raining event is actual. In this way, the usual “non-existence” interpretation of negation in event semantics is preserved. That is, the axiom of negation makes (13b) and (13c) logically equivalent.

As illustrated in (14a), two negations cancel out; and as (14b) shows, negation is downward entailing.

- (14) a. Mary slept. \Leftrightarrow Mary did not not sleep.
 b. Mary did not eat. \Rightarrow Mary did not eat an egg.

These two properties are ensured by the two following theorems, which are consequences of our axiom:

- (15) $\forall P. [\exists e \in P. \text{actual}(e)] \leftrightarrow [\exists e \in \text{Neg}(\text{Neg}(P)). \text{actual}(e)]$
 (If there is an actual P event, then there is an actual anti-anti- P event, and vice versa.)
- (16) $\forall P. \forall P' \subseteq P. [\exists e \in \text{Neg}(P). \text{actual}(e)] \rightarrow [\exists e \in \text{Neg}(P'). \text{actual}(e)]$
 (If there is an actual anti- P event, then for any subset P' of P , there is an actual anti- P' event.)

In addition to preserving the correct truth conditions of negated sentences, the negative events that the *Neg* function makes available reify the absence of events of a certain sort. As mentioned in Section 1, negative events have been previously argued to be appropriate for the analysis of negated perception reports, negated causation reports, and other phenomena. We build on these analyses by taking all uses of verb phrase negation to involve the *Neg* function. Previous work has not shown how negative events are introduced in a compositional fashion. The remainder of this paper presents a concrete proposal to this effect.

4 The compositionality problem

Having presented our foundational notions concerning negative events, we turn to the task of compositionally deriving the interpretation of linguistic utterances involving negation. We assume a Neo-Davidsonian approach to event semantics, in which events are related to individuals by thematic relations such as agent and theme (Carlson 1984; Parsons 1990).

The main challenge for a compositional semantic implementation is to ensure that all the relevant information is interpreted in the scope of the *Neg* function. We assume that *Neg* is introduced by VP negation, which takes syntactic scope below the subject at the surface level. We will focus on information conveyed by the subject, as in the following sentence:

(17) Mary did not sleep.

This sentence cannot be taken as relating Mary to an actual anti-sleeping event, as in (18a). If there was an actual anti-sleeping event, it would preclude all sleeping events from being actual, even those whose agents are people other than Mary. Clearly, the only kinds of events that are precluded by the truth of (17) are sleeping events by Mary. Therefore, we take (17) to state that there is an anti-Mary-sleeping event that is actual, as (18b).

- (18) a. $\exists e. \text{actual}(e) \wedge \text{agent}(e) = \text{Mary} \wedge e \in \text{Neg}(\lambda e. \text{sleep}(e))$
 b. $\exists e. \text{actual}(e) \wedge e \in \text{Neg}(\lambda e. \text{sleep}(e) \wedge \text{agent}(e) = \text{Mary})$

The challenge for compositional semantics is to resolve the scope mismatch between syntax, where *not* takes scope only over *sleep* but not over *Mary*, and semantics, where *Neg* takes scope over $\lambda e. \text{sleep}(e) \wedge \text{agent}(e) = \text{Mary}$.

There are several well-known strategies for resolving scope mismatches. Here we adopt a semantic strategy. Specifically, we will assume that negated verb phrases denote higher-order functions that take their subjects as arguments and internally reorder the relative scope of subject and negation. The advantage of this strategy is that it is directly compositional; that is, it does not require a separate level of logical form or LF (Jacobson 2012).

An alternative approach, which we do not pursue here, would start from the assumption that the relative scope of subject and negation is determined syntactically. For example, one could adopt the VP-internal subject hypothesis, according to which subjects originate within the VP and move out of it to their surface position, where they are pronounced (Koopman & Sportiche 1991). A nonquantificational subject like *Mary* would be interpreted in its original position within the VP, that is, in the scope of negation.

No matter how the relative scope of subject and negation is determined, a slightly more complex situation arises in the case of quantificational subjects. When such a subject appears in the same clause as negation, their relative scope depends on whether the clause is finite or nonfinite and on whether the quantifier is universal.

Consider first the unembedded case. In (19), the quantifiers *somebody* and *nobody* take scope above negation, while the quantifier *everybody* can take scope either above or below negation (Kroch 1974; Beghelli & Stowell 1997). Regarding *nobody*, we set aside the phenomenon of negative concord. In the only remaining interpretation, the two negations cancel out; thus, (19b) means that everybody left.

- (19) a. Somebody did not leave. $\exists > \neg$
 b. Nobody did not leave. $\neg\exists > \neg$
 c. Everybody did not leave. $\forall > \neg$ or $\neg > \forall$

These quantifiers behave analogously when they are embedded in finite clauses under perception verbs. That is, (20a) and (20b) are scopally unambiguous, while (20c) is scopally ambiguous, in exactly the same way as their unembedded counterparts in (19).

- (20) a. Serge saw that somebody did not leave. $\exists > \neg$
 b. Serge saw that nobody did not leave. $\neg\exists > \neg$
 c. Serge saw that everybody did not leave. $\forall > \neg$ or $\neg > \forall$

When the same quantifiers are embedded in nonfinite rather than finite clauses under perception verbs, they always take scope above negation:

- (21) a. Serge saw somebody not leave. $\exists > \neg$
 b. Serge saw nobody not leave. $\neg\exists > \neg$
 c. Serge saw everybody not leave. $\forall > \neg$

We assume that in these sentences, the quantifier even takes semantic scope over the perception verb. For example, (21c) is equivalent to stating that for every person x , Serge saw x not leave (van der Does 1991).

5 A continuized grammar for negative events

Having sketched various strategies that resolve scope mismatches between subject and negation, we now present our implementation of the semantic strategy. We rely on the notion of continuations (Barker & Shan 2014). In a continuized grammar, some terms are type-raised so as to control the order in which different constituents in the sentence are evaluated. Here, we use continuations to give VP negation semantic scope outside of its syntactic scope by adding an extra argument f to all verbal projections. This is our continuation variable; f is mnemonic for the future of the derivation. In doing so, we follow Champollion (2015), another continuized treatment of event semantics. We deviate from Champollion (2015) in our treatment of negation, as well as by introducing existential quantifiers over events at the sentence level and not at the level of the verb.

Continuations can be thought of as a communication channel through which constituents in a higher position (such as subjects) can send information to a lower position (such as below negation). For instance, in (17), *Mary* is outside of the scope of the negated VP but needs to send the information that *Mary* is the agent into that scope. In a continuized grammar, *Mary* can do so through the continuation of the VP. In the scopally ambiguous sentence (19c), we obtain the inverse-scope reading *Not everybody left* by sending the universal quantifier through the continuation of the negated VP continuation; if we abstain from doing so, the result is the surface-scope

reading *Everybody failed to leave*.

5.1 A grammar for simple statements

We follow the standard approach to Neo-Davidsonian compositional semantics and assume that all verbal projections take an argument of type v , the type of events (e.g. Carlson 1984; Champollion 2017). We expose the continuation of all verbal projections by adding an extra argument of type $\langle v, t \rangle$. We write e for variables of type v and f for variables of type $\langle v, t \rangle$, such as our continuation variables.

The type of an ordinary verb such as *sleep* is $\langle \langle v, t \rangle, \langle v, t \rangle \rangle$. Since this is also the type of all verbal projections, we abbreviate it as **vp**.

$$(22) \quad \llbracket \text{sleep} \rrbracket \equiv \lambda f \lambda e. \text{sleep}(e) \wedge f(e)$$

This term expects its continuation f , a set of events, and returns an event predicate that intersects f with its intrinsic meaning *sleep*, the set of all sleeping events.

Our lexical entry for VP negation, of type $\langle \mathbf{vp}, \mathbf{vp} \rangle$, is a modifier: it combines with a verb phrase V and returns a predicate of the same type as V .

$$(23) \quad \llbracket \text{not} \rrbracket \equiv \lambda V \lambda f \lambda e. e \in \text{Neg}(\lambda e'. V(f)(e'))$$

This entry sends the verb phrase V to which it applies into the scope of a *Neg* operator. The resulting predicate, in turn, sends its continuation f into the scope of *Neg* and V . This is what allows the continuation f to play the role of a communication channel by which the subject can send information into the scope of negation. Before illustrating this with an example, we need to specify a few other aspects of our grammar.

Following Carlson (1984) and much subsequent work, we assume that proper names associate with thematic roles to yield event predicates. We write θ for thematic roles, and we also use θ as subscripts to keep track of these roles in the syntax.

$$(24) \quad \llbracket \text{Mary} \rrbracket_{\theta} \equiv \lambda e. \theta(e) = \text{Mary}$$

While this term could serve as the continuation of a VP, doing so would use up the f argument of the VP, thereby closing the communication channel. This would prevent any additional information from being sent down from a higher position in the syntactic tree. The following silent type-raising operator ensures that the communication channel remains open:

$$(25) \quad \uparrow \equiv \lambda P \lambda V \lambda f. V(\lambda e. P(e) \wedge f(e))$$

This term is of type $\langle \langle v, t \rangle, \langle \mathbf{vp}, \mathbf{vp} \rangle \rangle$. It sends its argument P (for instance, $\llbracket \text{Mary} \rrbracket_{ag}$) through the continuation of the verb phrase V , but without closing the channel.

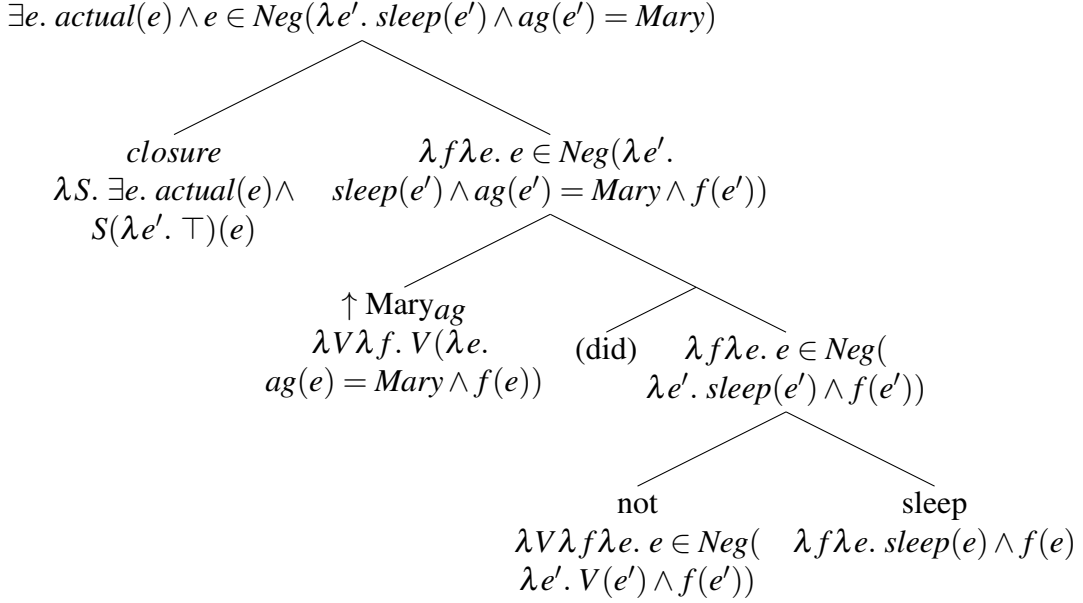


Figure 1 Deriving “Mary did not sleep”.

Following standard practice in event semantics, we assume that at the top of every sentence an existential closure operation applies:

$$(26) \quad \text{closure} \equiv \lambda S. \exists e. \text{actual}(e) \wedge S(\lambda e'. \top)(e)$$

In our system, this closure operator serves a double purpose. First, it existentially quantifies over an actual event and passes it to the sentence S ; second, it closes off the continuation of S by using the trivial predicate $\lambda e'. \top$, which holds of all events. To ensure that this operator takes scope over sentences, our system assigns them the type $\langle \mathbf{vp}, \mathbf{vp} \rangle$. This has the consequence that arguments of type $\langle v, t \rangle$, such as $[[\text{Mary}]]_{\text{ag}}$, must undergo type-raising by the \uparrow operator before combining with the VP. While a VP (of type \mathbf{vp} , that is, $\langle \langle v, t \rangle, \langle v, t \rangle \rangle$) could in principle combine by functional application with a noun phrase of type $\langle v, t \rangle$, the resulting constituent would be of type $\langle v, t \rangle$ and thus not a suitable argument to the closure operator at the top of the tree.

The fragment defined so far allows us to analyze the sentence *Mary did not sleep* as in Figure 1. The resulting formula is true just in case there is an actual event among the anti-Mary-sleeping events. In other words, this formula states that no sleeping event by Mary is actual; that is, Mary did not sleep.

Let us now turn to the semantics of quantifiers. We assume that all quantifiers over individual variables are restricted to actual (rather than non-actual) individuals;

to avoid clutter, we omit this restriction from the formulas. Our semantics of *nobody* is compositionally derived from the semantics of *not* and *somebody*, in the sense that $\llbracket \text{nobody} \rrbracket_{\theta} = \lambda V. \llbracket \text{not} \rrbracket(\llbracket \text{somebody} \rrbracket_{\theta}(V))$.

$$(27) \quad \llbracket \text{somebody} \rrbracket_{\theta} \equiv \lambda V \lambda f \lambda e. \exists x. V(\lambda e'. \theta(e') = x \wedge f(e'))(e)$$

$$(28) \quad \llbracket \text{nobody} \rrbracket_{\theta} \equiv \lambda V \lambda f \lambda e. e \in \text{Neg}(\lambda e'. \exists x. V(\lambda e''. \theta(e'') = x \wedge f(e''))(e'))$$

$$(29) \quad \llbracket \text{everybody} \rrbracket_{\theta} \equiv \lambda V \lambda f \lambda e. \forall x. \exists e' \leq e. V(\lambda e''. \theta(e'') = x \wedge f(e''))(e')$$

These quantifiers are already of type $\langle \mathbf{vp}, \mathbf{vp} \rangle$ and cannot be modified by the operator \uparrow . They combine directly with a verb phrase V to which they send information about the individual(s) they quantify over.

Our closure operator states of only one event that it is actual. For universal quantifiers like *everybody*, this creates a problem, since they quantify over a multitude of events; when these quantifiers appear in unembedded sentences, each of these events is actual. The entry in (29) resolves this problem in the spirit of Taylor (1985), Schein (1993) and others, by assuming that *everybody* includes an existential quantifier over parts of a sum event. It is this sum event that the closure operator requires to be actual. We then assume that actuality distributes from sum events to its parts. To state this formally, we assume that events are ordered by a mereological parthood relation \leq ; for details, see Champollion & Krifka (2016). Distributivity of actuality is then ensured by the following axiom:

$$(30) \quad \textbf{Distributivity of Actuality Axiom}$$

$$\forall e. [\text{actual}(e) \rightarrow \forall e' \leq e. \text{actual}(e')]$$

(Every part of any actual event is itself actual.)

In (31) through (33), we show the results of derivations for sentences of the form Q *did not leave*, where Q is one of the quantifiers in (27) through (29).

$$(31) \quad \text{Somebody did not leave.}$$

- a. $\text{closure}(\llbracket \text{somebody} \rrbracket_{\text{ag}}(\llbracket \text{not} \rrbracket \llbracket \text{leave} \rrbracket))$
- b. $\exists e. \text{actual}(e) \wedge \exists x. e \in \text{Neg}(\lambda e'. \text{leave}(e') \wedge \text{ag}(e') = x)$

Formula (31b) is true just in case there exists a person who is not the agent of any actual leaving event; that is, there is somebody who did not leave.

$$(32) \quad \text{Nobody did not leave.}$$

- a. $\text{closure}(\llbracket \text{nobody} \rrbracket_{\text{ag}}(\llbracket \text{not} \rrbracket \llbracket \text{leave} \rrbracket))$
- b. $\exists e. \text{actual}(e) \wedge e \in \text{Neg}(\lambda e'. \exists x. e' \in \text{Neg}(\lambda e''. \text{leave}(e'') \wedge \text{ag}(e'') = x))$

Formula (32b) states that there is no actual event e' and person x such that e' precludes

all leavings by x . Consider an arbitrary individual x_0 . According to the axiom of negation (11), using the converse of the right-to-left direction, given that there is no actual event that precludes all leavings by x_0 , it follows that some leaving by x_0 is actual. This formula is therefore true if and only if everybody left.

- (33) Everybody did not leave.
- a. $\text{closure}(\llbracket \text{everybody} \rrbracket_{ag}(\llbracket \text{not} \rrbracket \llbracket \text{leave} \rrbracket))$
 - b. $\exists e. \text{actual}(e) \wedge \forall x. \exists e' \leq e. e' \in \text{Neg}(\lambda e''. \text{leave}(e'') \wedge ag(e'') = x)$

According to (33b), there is an actual event e which includes a subevent e' for every person x , such that each e' precludes all leavings by x . Because of axiom (30), which relates actuality to event mereology, all of the e' are actual; hence nobody left.

While for *somebody* and *nobody*, the interpretation derived is the only available one, the semantics for *everybody* in (33) only derives the surface scope reading “Nobody left”. To derive the inverse scope reading “Not everybody left”, we stipulate a second lexical entry for the quantifier $\llbracket \text{everybody} \rrbracket$:

- (34) $\llbracket \text{everybody}' \rrbracket_{ag} \equiv \lambda e. \forall x. (\exists e' \leq e. ag(e') = x)$

To avoid overgenerating inverse scope readings in nonfinite clauses such as (21c), we assume that the grammar constrains the distribution of this entry so it can only appear in finite clauses. We leave the explanation and implementation of this constraint for future work.

5.2 Perception reports with and without negation

In this subsection, we extend our fragment of English to account for finite and nonfinite complements of the perception verb *see*. We will write *see (that)* to indicate that *see* takes a finite complement, and simply *see* to indicate that it takes a nonfinite one.

Barwise (1981) argues that finite perception reports are compatible with scenarios in which the subject has indirect evidence of the truth of the complement and must be accompanied by some sort of understanding, while nonfinite perception reports require direct evidence but not necessarily understanding. We formalize this observation by treating perception verbs with finite complements as involving a proposition and an individual who mentally comprehends it, and by treating perception verbs with nonfinite complements as involving a perceived event and an individual who physically perceives it. To keep track of this difference, we write the relevant predicates as see_{nonfin} and see_{fin} . Our logic is entirely standard. The interpretation function is the usual one in the simply typed λ -calculus. In particular, we do not need specific clauses for perception verbs, unlike, for example, van der

Does (1991). We handle the interaction of perception verbs with negation and quantifiers in the syntax-semantics interface.

We use the operator \wedge , which maps propositions of type t to their intensions. In a possible-worlds framework such as Montague (1974), intensions can be thought of as functions from possible worlds to truth values. Since we are not committed to possible worlds, we remain neutral on the implementation of \wedge .

Both our lexical entries combine with a complement V of type \mathbf{vp} , but they differ in the way they treat it:

- (35) a. $\llbracket \text{see (that)} \rrbracket \equiv \lambda V \lambda f \lambda e. \text{see}_{\text{fin}}(e) \wedge \text{th}(e) = \wedge[\text{closure}(V)] \wedge f(e)$
 b. $\llbracket \text{see} \rrbracket \equiv \lambda V \lambda f \lambda e. \text{see}_{\text{nonfin}}(e) \wedge \exists e'. \text{th}(e) = e' \wedge V(\lambda e''. \top)(e') \wedge f(e)$

The entry (35a) combines with a finite complement. It describes a seeing event whose theme is the (intension of the) proposition obtained by applying the closure operator to V . That is to say, its theme is the proposition that V is satisfied by an actual event. The entry (35b) combines with a nonfinite complement. It describes a seeing event whose theme is an event that satisfies V .

We adopt the view favored by many semanticists on perception reports since Barwise (1981), namely, that the nonfinite verb phrase forms a clausal constituent with a preceding noun phrase (but see Clark & Jäger 2000 for a different view). We introduce a second mode of composition in addition to the usual functional application. This mode of composition, which we call *Nonfinite Clause Composition*, combines a noun phrase and a nonfinite verb phrase. We assume that Nonfinite Clause Composition is obligatorily triggered by nonfinite morphology and thus comes to play in all and only nonfinite clauses.

Nonfinite Clause Composition forces the noun phrase constituent to take semantic scope over the perception verb and hence over VP negation if it occurs; this accounts for the wide scope of quantifiers we observed in (21).

(36) **Nonfinite Clause Composition (NCC)**

A verb phrase V of type \mathbf{vp} and a noun phrase Q of type $\langle \mathbf{vp}, \mathbf{vp} \rangle$ can merge into a constituent $\lambda P \lambda f. Q(\lambda f'. P(\lambda f'' \lambda e. V(f')(e) \wedge f''(e))(f))(\lambda e'. \top)$ of type $\langle \langle \mathbf{vp}, \mathbf{vp} \rangle, \mathbf{vp} \rangle$.

This mode of composition corresponds to the introduction of the following (type-raising) term in the derivation:

- (37) $@_{\text{NCC}} \equiv \lambda Q \lambda V \lambda P \lambda f. Q(\lambda f'. P(\lambda f'' \lambda e. V(f')(e) \wedge f''(e))(f))(\lambda e'. \top)$

For example, the meaning derived for the nonfinite clauses *Mary leave* and *everybody leave* in (38) and (39) is as follows:

- (38) a. $@_{\text{NCC}}(\uparrow \llbracket \text{Mary} \rrbracket_{\text{ag}}) \llbracket \text{leave} \rrbracket$
 b. $\lambda P \lambda f. P(\lambda f' \lambda e'. \text{leave}(e') \wedge \text{ag}(e') = \text{Mary} \wedge f'(e'))(f)$

Because *Mary* is non-quantificational, this term is relatively simple: *Mary leave* expects to combine with a verb *P* such as *see*, and the perceived event, which is determined by the argument of *P*, will be one of *Mary* leaving.

- (39) a. $@_{\text{NCC}} \llbracket \text{everybody} \rrbracket \llbracket \text{leave} \rrbracket$
 b. $\lambda P \lambda f \lambda e. \forall x. \exists e' \leq e. P(\lambda f' \lambda e''. \text{leave}(e'') \wedge \text{ag}(e'') = x \wedge f'(e''))(f)(e')$

Here, however, the quantifier takes scope over *P*. This will lead to the introduction of one seeing event *e'* for each person *x*. The corresponding perceived event is an event of *x* leaving.

We are now in a position to analyze both finite and nonfinite perception reports, independently of whether their complement contains a VP negation or not. First, let us see how *Serge saw Mary not leave* is analyzed:

- (40) a. Serge saw Mary not leave.
 b. $\text{closure}(\uparrow \llbracket \text{Serge} \rrbracket_{\text{exp}}(@_{\text{NCC}}(\uparrow \llbracket \text{Mary} \rrbracket_{\text{ag}})(\llbracket \text{not} \rrbracket \llbracket \text{leave} \rrbracket) \llbracket \text{see} \rrbracket))$
 c. $\exists e. \text{actual}(e) \wedge \text{see}_{\text{nonfin}}(e) \wedge \exists e'. \text{th}(e) = e' \wedge e' \in \text{Neg}(\lambda e''. \text{leave}(e'') \wedge \text{ag}(e'') = \text{Mary}) \wedge \text{exp}(e) = \text{Serge}$

The derived formula is true if and only if there exists an actual event of physical perception whose experiencer is *Serge* and whose theme is *e'*, a precluder of all leaving-by-*Mary* events. This does not guarantee that *e'* is actual, and hence that *Mary* did not leave. To ensure this inference, we postulate the following axiom (which is not specific to negative events):

- (41) **No Hallucination Axiom (nonfinite perception reports)**
 $\forall e. [\text{see}_{\text{nonfin}}(e) \wedge \text{actual}(e)] \rightarrow \text{actual}(\text{th}(e))$
 (The theme of any actual nonfinite seeing event is itself an actual event.)

In the case at hand, this axiom ensures that *e'* is actual; hence, *Mary* did not leave.

We now turn to quantificational noun phrases in the two types of perception reports. We illustrate with the quantifier *nobody*, starting with the nonfinite case:

- (42) a. Serge saw nobody leave.
 b. $\text{closure}(\uparrow \llbracket \text{Serge} \rrbracket_{\text{exp}}(@_{\text{NCC}} \llbracket \text{nobody} \rrbracket_{\text{ag}} \llbracket \text{leave} \rrbracket \llbracket \text{see} \rrbracket))$
 c. $\exists e. \text{actual}(e) \wedge e \in \text{Neg}(\lambda e'. \exists x. \text{see}_{\text{nonfin}}(e') \wedge \exists e''. \text{th}(e') = e'' \wedge \text{leave}(e'') \wedge \text{ag}(e'') = x \wedge \text{exp}(e') = \text{Serge})$

The derived formula states that there is no actual seeing event by *Serge* whose theme

is a leaving event by any person. In other words, Serge did not physically see anyone leaving. This formula does not entail anything about whether anyone left or not, only that no such event was perceived by Serge. This is different in the finite case:

- (43) a. Serge saw (that) nobody left.
 b. $closure(\uparrow \llbracket \text{Serge} \rrbracket_{exp}(\llbracket \text{see (that)} \rrbracket(\llbracket \text{nobody} \rrbracket_{ag} \llbracket \text{leave} \rrbracket)))$
 c. $\exists e. actual(e) \wedge see_{fin}(e) \wedge th(e) = \wedge [\exists e'. actual(e') \wedge e' \in Neg(\lambda e''. \exists x. leave(e'') \wedge ag(e'') = x)] \wedge exp(e) = Serge$

The formula in (43c) is true just in case Serge is experiencing a state of mental perception (see_{fin}) whose theme is the proposition that no one left. We encode the fact that *saw (that)* is factive (in contrast to a nonfactive verb such as *believe (that)*) in an axiom. Here we use the \vee operator to access the extension of the proposition in question. In terms of Montague (1974), \vee is the inverse of \wedge ; it takes an intension p and checks whether p applies to the actual world.

- (44) **No Hallucination Axiom (finite perception reports)**
 $\forall e. [see_{fin}(e) \wedge actual(e)] \rightarrow \vee th(e)$
 (The theme of any actual finite seeing event is a true proposition.)

Our fragment thus compositionally derives the correct semantics of finite and nonfinite negative perception reports.

5.3 Reports of negative causation

We now extend our fragment so as to handle reports of negative causation such as (6), repeated here with the subject of its nonfinite clause made explicit:

- (45) I_i kept the child awake by PRO_i not turning off the light.

We assume that causation is a relation between events (Parsons 1990), and that the preposition *by* expresses this relation. We write $cause(e', e)$ to state that e' causes e .

- (46) $\llbracket \text{by} \rrbracket = \lambda S \lambda V \lambda f \lambda e. V(f)(e) \wedge \exists e'. cause(e', e) \wedge S(\lambda e''. \top)(e')$

This applies to a nonfinite clause S of type **vp** and returns an adverbial of type $\langle \mathbf{vp}, \mathbf{vp} \rangle$, which intersects a VP V with the set of events caused by an S event. The following axiom ensures that only actual events can serve as causes of actual events:

- (47) **Causal Efficacy Axiom**
 $\forall e \forall e'. [cause(e', e) \wedge actual(e)] \rightarrow actual(e')$
 (The cause of any actual event is itself actual.)

The formula we derive for (45) based on the LF in (48a) is given in (48b).

- (48) a. $\text{closure}(\uparrow \llbracket \mathbf{I}_i \rrbracket \text{ag}(\llbracket \text{by} \rrbracket (\uparrow \llbracket \text{PRO}_i \rrbracket \text{ag}(\llbracket \text{not} \rrbracket \llbracket \text{turning off the light} \rrbracket))$
 $(\llbracket \text{keep awake} \rrbracket \llbracket \text{the child} \rrbracket \text{exp})))$
 b. $\exists e. \text{actual}(e) \wedge \text{ag}(e) = I \wedge \text{keep_awake}(e) \wedge \text{exp}(e) = \text{child} \wedge \exists e'.$
 $\text{cause}(e', e) \wedge e' \in \text{Neg}(\lambda e''. \text{ag}(e'') = I \wedge \text{turn_off}(e'') \wedge \text{th}(e'') = \text{light})$
 (There is an actual event of the speaker keeping the child awake, and it is caused by an event of the speaker not turning off the light.)

This formula causally relates a keeping-the-child-awake event to a negative turning-off-the-light event by the speaker. The Causal Efficacy Axiom in (47) ensures that this negative event is actual. Given the Axiom of Negation in (11), this in turn entails that no turning-off-the-light event by the speaker is actual.

6 Previous work

We are aware of two authors who have proposed a non-standard formalization of negation in event semantics: [Krifka \(1989\)](#) and [Higginbotham \(1983, 2000\)](#).

6.1 [Krifka \(1989\)](#): Negation based on fusion

As observed by [Krifka \(1989\)](#), the following sentence is ambiguous:

- (49) Mary did not laugh for two hours.

On one reading, negation takes scope over the temporal adverbial; this reading states that it is not the case that Mary laughed for two hours. On the other reading, negation takes scope below the temporal adverbial and the sentence means that for two hours, Mary did not laugh.

[Krifka](#) derives the two readings of (49) using a single entry for *for two hours*. Since he treats *for two hours* as a modifier of event predicates, he needs to let *Mary did not laugh* denote an event predicate. This in turn requires treating negation as a modifier of event predicates. To this purpose, he first defines a “maximal event” as an event that is the mereological sum, or fusion, of all events that take place within a given time interval. [Krifka’s](#) definition of maximal event relies on the runtime function τ , which maps events to the time intervals at which they occur; the subinterval relation between temporal intervals, \subseteq_T ; and the mereological sum of a set of events, which [Krifka](#) writes as FUSION. [Krifka’s](#) definition is as follows:

- (50) $\forall e. \mathbf{MXE}(e) \leftrightarrow (\exists t. e = \text{FUSION}_{\mathbf{E}}(\lambda e. \tau(e) \subseteq_T t))$
 (An event is maximal if and only if it is the sum of all the events which occur within some temporal interval.)

Because such a maximal event e contains all events that happen during an interval t , inspecting its parts is tantamount to inspecting what happened during t . For instance, if e is a maximal event whose parts all took place during t , and if there is no event of Mary laughing included in e , it follows that Mary did not laugh during t . The negation of an event predicate P can now be expressed by stating that the maximal event at a given time does not contain any event that satisfies P . The following lexical entry relies on the mereological parthood relation between events.

$$(51) \quad \llbracket \text{not} \rrbracket_{\text{Krifka}} = \lambda P \lambda e. \mathbf{MXE}(e) \wedge \neg \exists e'. (P(e') \wedge e' \leq e)$$

By combining this treatment of negation with an entry for *for two hours* that essentially states that its argument is an event whose runtime is a two-hour interval, [Krifka](#) correctly predicts the two readings of (49) depending on whether negation takes scope above or below the temporal adverbial.

Although the maximal fusions that appear in [Krifka's](#) account of negation appear similar to negative events, this resemblance is only superficial ([Champollion 2015](#)). A maximal event is the sum of everything that happened during some time interval t . It therefore cannot be used to represent any single event that did or did not occur during t . For example, suppose John kept his child awake by not turning off the light. On [Krifka's](#) system, the verb phrase *not turn off the light* will denote the property of being a maximal event that does not contain any turning-off-the-light events. This event will contain all kinds of events that bear no causal relation to John keeping his child awake. This makes maximal events unsuitable for the analysis of negative causation reports. Similar problems occur in connection with other phenomena such as negative perception reports or reference to negative events.

6.2 [Higginbotham \(1983, 2000\)](#): Negative predicates

Because of the similarity between (52a) and (52b), [Higginbotham \(1983\)](#) suggests that in some cases negation combines with a predicate P to form a “not- P ” event predicate. He credits [Judith Thomson](#) with the generalization that such pairs of sentences are equivalent whenever the relevant verbs are antonyms.

- (52) a. John saw Mary not leave.
b. John saw Mary stay.

Elaborating on this idea, [Higginbotham \(2000\)](#) proposes that the relation between predicates P (such as *leave*) and their negated forms \bar{P} (such as *not leave*) obeys the following axiom, where τ sends events to their runtimes and \circ is temporal overlap:

$$(53) \quad \forall t. (\neg \exists e. (\tau(e) \circ t \wedge P(e)) \rightarrow (\exists e'. \bar{P}(e') \wedge \tau(e') = t)$$

(If no P event starts or ends during t , there is a \bar{P} event whose runtime is t .)

This axiom ensures that from the absence of any P events of a given kind we can conclude the existence of a non- P event. For example, if there is no leaving event by Mary, then there is a non-leaving event by her.

Unlike our axiom of negation in (11), this axiom is not a biconditional. Therefore, it allows P events and \bar{P} events to co-occur. This fails to rule out models that contain both a Mary-leaving and a Mary-not-leaving event.

Our own proposal is in the spirit of Higginbotham (2000) but improves on it in that for us, *Mary left* and *Mary did not leave* cannot both be true (see Section 3).

7 Conclusion

Negative events have been proposed to describe the meaning of VP negation as a way to generalize event semantic analyses to utterances with negated clauses; but it is not clear conceptually and formally just what it means for an event to be negative.

In addition to clarifying the nature of negative events, a linguistic theory of negative events should ensure that pairs of sentences such as *Mary left* and *Mary did not leave* are contradictory, and should lead itself to a compositional implementation.

We have proposed that to every set of events P there corresponds a set $Neg(P)$ of events that cannot co-occur with any event in P . We have distinguished between actual and nonactual events, and suggested that $Neg(P)$ contains all events (actual or not) which preclude every event in P from being actual. We have constrained the function Neg so that any event in $Neg(P)$ is actual if and only if no event in P is. Given this, the events in $Neg(P)$ can be thought of as anti- P events.

We have shown how Neg can be introduced by linguistic negation in the context of a compositional syntax-semantics interface. Linguistic negation takes syntactic scope below the subject at the surface level, but Neg needs to be able to take semantic scope above it; we have resolved this type mismatch by using continuations.

The fragment presented here focuses on positive and negative perception reports with ordinary and quantified subjects. We have followed Barwise (1981) in distinguishing two senses of *see*, corresponding to finite and nonfinite complements. We have also sketched an analysis of negative causation reports.

Our formalization also readily accounts for the possibility of anaphoric reference. We believe that the combination of the logic and the syntax-semantics interface developed here is expressive enough to compositionally handle temporal modification or distributivity analogously for negated and non-negated constructions. For reasons of space, we have not included these analyses here.

Future work could use the Neg function in the formalization of failing, omitting, or refraining events (e.g. Mossel 2009; Willemsen 2016), and investigate nonclassical logics that could be achieved by weakening the axiom of negation.

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Timothée Bernard
Laboratoire de linguistique formelle
Case Postale 7031
5, rue Thomas Mann
75205 Paris Cedex 13
France
timothee.bernard@ens-lyon.org

Lucas Champollion
Department of Linguistics
New York University
10 Washington Place
New York, NY 10003
United States
champollion@nyu.edu