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Negative Events and Compositional Semantics

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Abstract

Motivated by intuitive parallels between event descriptions with and without linguistic negation, we develop a formalization of negative events. We propose that verbal negation denotes a function Neg, which sends any set of events P to a set $Neg(P)$ constrained by a principle ensuring that any event in $Neg(P)$ occurs if and only if no event in P does. This allows us to construe the events in $Neg(P)$ as negative, "anti-P", events. Our formalization of Neg is conceptually related to truthmaker semantics but only requires standard logical tools, and it is compatible with standard versions of event semantics. We develop an explicit syntax-semantics interface and compositional analyses of the interaction of negation with disjunction, conjunction, quantifiers, and nonfinite perception reports.

1 INTRODUCTION

This paper develops a formalization of the notion of a negative event and demonstrates its usefulness in compositional natural language semantics. We provide a framework in which negative events are introduced by the word *not* into an otherwise fairly standard system whose syntactic assumptions are independent of the notion of negative event adopted.

Should any events that are not ϕ-ing events be regarded as events of not ϕ-ing? And if so, which events should be regarded in this way? This is the problem of negative events, a standing question in event semantics. A *negative event* in our sense is any event to which an ordinary negated clause or sentence applies. For example, just as a sentence like *John left* describes ordinary nonnegative events, a sentence like *John didn't stay* describes negative events. In this specific case, and in similar cases that also involve antonyms, it is possible (but not necessary) to think of the two sentences as describing the same events: any leaving would be a non-staying and vice versa. In this case, the same event would be seen as negative under one description and ordinary under another. Thus we do not appeal to any ontological or sortal distinction which partitions the set of events into intrinsically negative and nonnegative (i.e., positive) events.[1] In general, though, many kinds of negative events, such as those described by *John didn't laugh*, cannot be collectively picked out by any positive sentence. This may even vary from one language to another depending on the availability of antonyms.

Our proposal is motivated by an intuitive parallel between event descriptions with and without linguistic negation. Events have been integrated into semantic analyses of a wide variety of natural language phenomena (Davidson, 1967; Parsons, 1990 and references therein; Krifka, 1989; Lasersohn, 1995; Champollion, 2015; von Stechow & Beck, 2015):

(1) a. I saw Mary leave. *Perception report*
b. I put the child to sleep by turning out the light. *Causation*
c. Mary's departure made John sad. *Nominalization*
d. It rained and snowed. *Conjunction*
e. Every student sang. *Quantification*
f. Calpurnia must convince Caesar. *Modality*

These constructions are compatible with linguistic negation, which raises the question what kinds of events, if any, underlie the negated expressions that result:

(2) a. I saw Mary not leave.
b. I kept the child awake by not turning out the light.
c. Mary's non-departure surprised John.
d. It didn't rain and snow.
e. Every student didn't sing.
f. Calpurnia cannot convince Caesar.

The theory of negation we will develop is broadly similar to a number of previous analyses of these kinds of examples which share the assumption that linguistic negation (that is, the word *not*) introduces events or states into the semantics (Higginbotham, 1983, 2000; Krifka, 1989; de Swart & Molendijk, 1999). Negative events have also been postulated in semantic accounts of a variety of phenomena such as anaphoric reference (Higginbotham, 1983, 2000); negated definite event descriptions and modification of negated clauses (Przepiórkowski, 1999); the temporal structure of discourse (de Swart & Molendijk, 1999); and temporal modifications of negated verb phrases (Krifka, 1989). Furthermore, negative events figure prominently in the philosophical literature on action and causation (Casati & Varzi, 2020, Sect. 2.5). As we show in detail in Section 10, these previous approaches either do not provide an explicit compositional semantic fragment or suffer from various deficiencies; this makes it worthwhile to develop a new and general approach.[2]

Accounts of negation that appeal to negative events contrast with traditional analyses of linguistic negation. In extensional frameworks, negation is traditionally analyzed as

1 This is in contrast to Bentham (1789, ch. 7, §10), who makes an ontological distinction between positive and negative events, though his distinction is not correlated (or at least not entirely) with the use of negation.

2 Common arguments for negative events are summarized and critically reviewed in Przepiórkowski (1999).

the truth function that maps True to False and vice versa. In possible world semantics, it is traditionally analyzed as the set-theoretic complement operation on sets of possible worlds. We will refer to these two analyses jointly as *complement negation*.[3] While this approach to linguistic negation is common and formally well-understood, it fits poorly with many event-based accounts of the phenomena in (2) above. This calls for a formally explicit and satisfactory formalization of negative events within a compositional framework.

The goal of this paper is threefold. First, we present an axiomatization of negative events based on an alternative to complement negation that we call *event negation*, and that accounts for the behavior of linguistic negation insofar as it coincides with classical negation. In particular, we provide a unified analysis of the interaction of event negation with conjunction, disjunction, quantifiers, and nonfinite perception reports.[4] The propositional part of our system can be seen as a natural generalization of unilateral truthmaker semantics in the sense of Fine (2017a,b). We discuss this connection briefly in Section 4 and in more detail in Champollion & Bernard (2024). However, both the system presented here and its presentation are self-contained and can be understood without reference to truthmaker semantics.

Second, we show in detail how to integrate our semantics of negation into a compositional framework. Following the tradition of Montague (1974), we emphasize the importance of exhibiting formal fragments of natural language. More than a mere exercise, such a development demonstrates the applicability of the proposed semantics and makes it possible to investigate its interaction with syntactic hypotheses. In particular, we study the mismatch between the syntactic scope of negation and its semantic scope with respect to the subject.

Third, through an extensive literature review, we establish that previous nonstandard approaches to negation cannot, and typically do not aim to, provide the basis for a unified account of the parallels illustrated above. This is due to their limited expressivity and/or their incompatibility with some central features of Davidsonian or neo-Davidsonian event semantics. We also highlight some previous work that can be adapted to our proposed formalization of negation and we argue in each case that this constitutes an improvement.

The paper is structured as follows. Section 2 provides additional motivation for the idea that negation introduces negative events. Section 3 provides technical and conceptual background. Section 4 presents our basic model of negative events and lays out a principle that governs their relation with ordinary events. Section 5 highlights some of its consequences. Section 6 describes how to add negative events to an existing model, and Section 7 discusses the interaction of our negation operator with conjunction and disjunction. Section 8 lays out the main principles that underlie the compositional fragment of English and includes a

3 This term is appropriate even for the extensional case if we assume the von Neumann encoding of True as $\{\emptyset\}$ and False as $\emptyset$, and if we take the relevant domain to be $\{\emptyset\}$, since the complement operation then maps True to False and vice versa.

4 Due to space constraints, we defer discussion of the other constructions in (2) to future work. For the same reason, we exclude constituent negation, interactions with time, tense and aspect, truth value gaps (i.e., phenomena related to presuppositions and homogeneity), and downward-entailing quantifiers and operators (except for a brief discussion of *no* and *every* in Section 8) from the scope of this paper.

brief discussion of quantifiers. We illustrate this fragment in Section 9 with an application to nonfinite perception reports. Section 10 reviews previous work on negation in event semantics. Section 11 concludes.

2 WHY WE NEED EVENT NEGATION

To get a better sense of why we need event negation, it helps to consider how far one can get by adopting complement negation in an otherwise event-based framework. To give a few examples among many, Champollion (2015) and de Groote & Winter (2015) analyze (3a) as in (3b), disregarding tense and aspect.

(3) a. John did not laugh.
    b. $\neg\exists e.\ [laugh(e) \wedge ag(e) = John]$

The formula in (3b) is true just in case there is no laughing event whose agent is John. This approach, termed *deflationism* in Payton (2021), does not require the introduction of any events over and above those that are already needed for ordinary nonnegated sentences. We defer a full discussion of deflationism to the beginning of Section 10. The limitations of this approach quickly become apparent when we consider negated perception reports (Higginbotham, 1983, 1999, 2000):

(4) I saw Mary not leave.

As Higginbotham observes, no relative scoping of complement negation and the event quantifier captures the truth conditions of this sentence:

(5) a. $\neg[\exists e.\ leave(e) \wedge ag(e) = Mary \wedge e \in [\![\text{I saw}]\!]]$
    (It is not the case that I saw Mary leave.)
    b. $\exists e.\ \neg[leave(e) \wedge ag(e) = Mary \wedge e \in [\![\text{I saw}]\!]]$
    (Some event is not a leaving event by Mary that I saw.)
    c. $\exists e.\ \neg[leave(e) \wedge ag(e) = Mary] \wedge e \in [\![\text{I saw}]\!]$
    (I saw some event that was not Mary leaving.)

Formula (5a) is true just in case there is no leaving event whose agent is Mary and which was seen by the speaker. Unlike sentence (4), this is compatible with Mary having left, as long as the speaker did not see her leave. As for (5b) and (5c), their truth conditions are almost trivially weak. Similar problems occur in connection with other constructions, such as causation reports and event nominalizations.

One might try to salvage complement negation by embracing truth conditions along the lines of (5) and then bridging the gap between assigned and observed truth conditions by appealing to pragmatics (e.g., Miller, 2003; Varzi, 2006; Schaffer, 2012). To our knowledge, this pragmatic kind of strategy seems to be driven more by the absence to date of a satisfactory semantic account of negative events than by empirical motivations (see Section 10.4). For example, none of the standard tests for pragmatic inferences, such as reinforceability and cancellability, apply to the inference from (4) to *Mary did not leave* (setting aside contexts in which Mary hallucinates).

Higginbotham (1983) convincingly argues that cases of perception reports should instead be analyzed as involving the perception of an event described by the (possibly negated) embedded clause. As we show in Section 10.3, the way he implements this idea has its own deficiencies, for it does not fully account for the basic semantic fact that whenever a sentence is true, its negation its false, and vice versa.[5] Furthermore, Higginbotham's account is not integrated within a compositional semantic fragment. But his basic idea is sound and in Section 9 we will develop our own account of perception reports in Higginbotham's spirit.

3 TECHNICAL AND CONCEPTUAL BACKGROUND

The core idea of Higginbotham's account of perception reports involves the perception of an event described by the embedded clause, whether that clause contains negation or not. Therefore we need to assume that clauses are descriptions of events; and since they often describe more than one event, this is most naturally done by taking them to denote sets of events. In event semantics, the set denoted by a sentence or clause is called the "event description" or "sentence radical" (e.g., Krifka, 1989).

We take the primary denotation of verbal negation to be event negation, which we will formalize as a unary operator on sets of events. We leave it open whether linguistic negation always denotes event negation or whether it sometimes also denotes complement negation (e.g., van der Does, 1991).

We do not rely on an assumed ontological or sortal distinction between states, events, and processes, unlike de Swart (1996) and de Swart & Molendijk (1999). We take all of these entities to be of a single type and refer to them collectively as "events"; this is synonymous with the term *eventualities* from Bach (1986).

We are neutral on whether negation always swaps the denotations of antonyms (Higginbotham, 1983). This is a language-dependent matter; for example, the German verbs *sprechen* ("to speak") and *schweigen* ("to be silent") are antonyms, but there is no corresponding pair of verbs in English. Our ontology of events is not limited by the lexicon. The same events may be described in one language by a lexical item (e.g., German *schweigen*) and in another language by a periphrastic construction (e.g., English *be silent*).

We develop our theory within an extensional variant of TY_2 (Gallin, 1975; Muskens, 1995), a version of the simply typed lambda calculus with a Boolean type t for truth values and two other basic types (Church, 1940). Usually, these two types are e for individuals and s for worlds. We use v for events and drop s.

TY_2 includes the usual logical operators (e.g., $\neg$, $\wedge$), and in particular the equality operator $=$. The logical operators are interpreted in the standard TY_2 way and have their standard types. In particular, $\neg$ has the type $\langle t, t\rangle$ and denotes the function that flips truth values; this is what we call "complement negation".

We write "$\lambda x \lambda y.\ \phi$" for "$(\lambda x.\ (\lambda y.\ \phi))$"; we omit brackets around the arguments of functional variables but not around the arguments of constant symbols. So we write "$\lambda P \lambda e \lambda t.\ P\, e \wedge ag(e) = t$", where P is a functional variable and ag is a constant symbol denoting a function of type $\langle v, t\rangle$. We use λ-terms to refer to their interpretation when this distinction is not crucial. We also equate sets with their characteristic functions, and we freely switch between set notation and function notation. So we use $e \in P$ and $P\, e$ interchangeably, and we use $P \subseteq Q$ and $\forall e.\ P\, e \rightarrow Q\, e$ interchangeably.

Even though we do not use possible worlds, the assumption that some events do not occur is crucial for our purposes. As formalized in the next section, we assume that the

5 The formulation we have chosen to express this basic fact leaves open how negation behaves with respect to truth value gaps.

sentence *Mary did not stay* is analyzed as involving an application of event negation to the set of events denoted by the sentence *Mary stayed*. Suppose that as a matter of fact, Mary did not stay and John did not laugh. One might take the set denoted by *Mary stayed* to be empty, on the grounds that no event of Mary staying occurred. But by the same logic, the set denoted by *John did not laugh* would likewise be empty, and event negation would then have the same output when applied to either set. This cannot be right: suppose that, in the situation described, I saw Mary not stay even though I failed to see John not laugh. Then the anti-stayings (of Mary) and the anti-laughings (of John) cannot be the same, since I saw one of the former but none of the latter.

Within the context of standard compositional semantics, this problem follows from two assumptions: (i) that verb phrases denote sets of events; (ii) that all events occur. There are thus different possible ways out of this problem. One way would be to deny the first assumption. Even within the confines of event semantics, alternatives to (i) have been developed (for instance in Champollion (2015), where verb phrases denote sets of sets of events) but for entirely different reasons and not in ways that solve the current issue. Here we deny the second assumption instead and assume that some events do not occur. For example, the construction of the Eiffel Tower occurred and we say that it is an *actual* event; Ponce de León's discovery of the fountain of youth did not occur and we say that it is a *nonactual* event. Thus we use the phrase *actual event* as a synonym for *occurring event*.[6]

This assumption corresponds to the assumption in possible world semantics that any false sentence (negated or not) denotes a set of nonactual worlds. We do not impose any arbitrary upper limit on the number of nonactual events, and so there may in principle be infinitely many such events in some of our models. Such liberal use of nonactual possibilia is sometimes objected to because of the lack of clear criteria of identity, as for example when Quine (1948) asks how many possible men there are in that doorway. But actual events already lack clear criteria of identity and are nevertheless in wide use in semantics (Kamp & Reyle, 1993, §5.1.3.1). Whether we use events or possible worlds, the nonactual entities we admit in our models are constrained by plausible semantic principles and we are not bothered by their mere presence. As Mossel (2009) puts it: "One need not feed them".

In the context of possible world semantics, one may think of actual events as events that occur in the actual world, and of nonactual events as those that do not (or conversely, one may think of the actual world as the world that contains all and only actual events). Similarly, when a predicate P applies to an actual event, one may think of the events in the denotation of the negation of P as occurring in counterfactual possible worlds. But this way of thinking is optional; our notion of actuality does not rest on the notion of possible worlds. In a setting such as ours which does not explicitly appeal to possible worlds, being actual can just as well be regarded as an unanalyzed property of occurring events.

6 Since the predicate *actual* applies to events and not to propositions, it should not be confused with the technical use of the sentential adverb *actually* in philosophical logic or with the sentential A operator in the logic of actuality (Crossley & Humberstone, 1977). The predicate *actual* is similar to the $E!$ predicate which is often found in free logic starting with the work of Leonard (1956) and which applies to entities which are actual. In free logic, singular terms may denote entities which, in our sense, are nonactual. Our existential quantifiers correspond to the outer quantifiers of free logic; the restriction to actual events corresponds to the inner quantifiers. For an overview of free logic, see Nolt (2020). However, the system that we use is implemented in a standard (non-free) higher-order logic (Gallin, 1975), as previously mentioned.

In order to express the core assumptions of our theory, we need to be able to place certain constraints on nonactual events. For this reason, we let our quantifiers range over both actual and nonactual events; that is to say, they are not existentially loaded. Thus, being (actual) needs to be distinguished from being in the range of a quantifier, contra Quine (1948). For example, a formula like $\exists e.\ rain(e)$ is true even if the only raining events are nonactual; in this sense, it should not be misread as stating the occurrence of a raining event. This is similar to the distinction between actualist and possibilist quantifiers in philosophical logic. Actualist quantifiers only range over actual entities and are thus existentially loaded; possibilist quantifiers also range over merely possible entities. In this respect, our quantifiers are similar to the possibilist quantifiers. We remain neutral, though, on whether all the events in the range of our quantifiers are possible or whether some of them are even impossible.

In order to be able to restrict the range of our quantifiers to actual events, we introduce a nonlogical constant *actual* of type $\langle v, t\rangle$. We call a predicate of events *instantiated* iff it contains an actual event, and we define the following shorthand:

(6) $Instantiated \stackrel{\text{def}}{=} \lambda P.\ [\exists e.\ actual(e) \wedge P\, e]$

By countenancing nonactual events, we can distinguish between different uninstantiated predicates. As an illustration, suppose again that Mary did not stay and John did not laugh. Both the set of Mary's staying events and the set of John's laughing events will fail to contain any actual events. However, they will typically contain different nonactual events and event negation will not in general map them to the same set of events.

4 A PRINCIPLE FOR NEGATIVE EVENTS

At the heart of our proposal is the function *Neg*, a unary operator on sets of events, which formalizes our concept of event negation. In the present TY_2 setting, the type of *Neg* is $\langle\langle v, t\rangle, \langle v, t\rangle\rangle$. For a predicate or set of events P, we refer to events in P as "P events" and to events in $Neg(P)$ as "anti-P events".

Any theory of negation should make predictions about entailment and contradiction with respect to sentences involving it, chief among them the fact that the negation of a sentence is judged true if and only if that sentence is judged false. When sentences are taken to denote sets of possible worlds and linguistic negation is analyzed in terms of set-theoretic complement, these predictions follow immediately; the same is the case when linguistic negation is analyzed as in classical propositional logic. However, as we have seen in the introduction, these options are not appropriate when sentences are analyzed as denoting sets of events. Here we analyze linguistic negation in terms of the *Neg* function. To ensure the familiar behavior of negation, we rely on a principle governing *Neg*:

(7) **Principle of Negation**
$\forall P.\ [[\exists e \in P.\ actual(e)] \leftrightarrow \neg[\exists e \in Neg(P).\ actual(e)]]$
(If there is an actual P event, then there is no actual anti-P event, and vice versa.)

This principle is related to a proposal in Higginbotham (2000), which we discuss in Section 10.3. The quantifier $\forall P$ is second-order and ranges over all sets of events. This includes not only the denotations of lexical event predicates such as the neo-Davidsonian translations of *stay*, *laugh*, *rain* and so on, but also complex predicates such as the translations of *John stay*, *Mary not laugh*, *eat an apple* and, more generally, every well-formed TY_2 predicate of type $\langle v, t\rangle$.[7]

In this paper, we take this function as a primitive and impose constraints on its behavior in the form of meaning postulates. The fact that our theory is based on a function that is constrained but not defined might give rise to ontological worries, since the behavior of this function varies from model to model and cannot be fully grasped (see Section 6). One could, if desired, understand *Neg* as a representation-language counterpart to the semantic clause for negation in unilateral truthmaker semantics (Fine 2017a, Champollion & Bernard 2024). In that case, the meaning postulates that we introduce in this paper would fall out as theorems and would not need to be stipulated; the tradeoff would consist in the introduction of a primitive exclusion relation between events, whose behavior would itself be governed by meaning postulates. Such an approach would also help ensure that the *Neg* function outputs predicates that avoid leakage in the sense of Bayer (1997) and Champollion (2016a), a concern that we set aside for present purposes. Here our goal is to show the linguistic application of negative events to the semantic analysis of various constructions in English, and our ability to do so relies on this principle, whether it is taken to be derived or primitive.

The meaning postulate in (7) is a biconditional which encodes two ideas. Its left-to-right direction ("No Gluts" in the terminology of Fine, 2017a) encodes the idea that $Neg(P)$ contains only events whose potential occurrence is incompatible with the occurrence of any event in P: a $Neg(P)$ event and a P event cannot, on pain of violating No Gluts, both be actual (or as we will also say, they cannot cooccur); in this sense, P events and anti-P events can be said to be mutually incompatible. To illustrate, let P be the set of all of Mary's departures (actual or not) and assume that $Neg(P)$ is the set of all her stayings (actual or not). Then No Gluts ensures that if Mary actually stayed, then none of her departures is actual; in other words, it is not the case that she both stayed and left. The right-to-left direction of the Principle of Negation ("No Gaps") encodes the idea that either some event in $Neg(P)$ occurs or some event in P does. No Gaps ensures that if Mary did not stay, she left; it is not the case that she neither stayed nor left. These directions (just as the axiom itself) can be expressed concisely using the *Instantiated* shorthand:

(8) a. **No Gluts**
$\forall P.\ [Instantiated(P) \rightarrow \neg Instantiated(Neg(P))]$

b. **No Gaps**
$\forall P.\ [\neg Instantiated(P) \rightarrow Instantiated(Neg(P))]$

To preclude misunderstandings, it is worth emphasizing that given that Mary did not stay, No Gaps does not require every actual event to be an anti-Mary-staying event; it merely ensures that some actual event is an anti-Mary-staying event.

We assume that linguistic negation (the word *not*) denotes the *Neg* function. Sentence (9a), for instance, will be translated as (9b), instead of as (9c), which uses complement negation.

7 In fact, and although we will not exploit this in the following, the range of P even includes sets not denoted by any TY_2 predicate, since there are only denumerably many such predicates, but there may be nondenumerably many sets of events in a model with at least denumerably many events. A slightly less powerful alternative would be to take the Principle of Negation as an axiom schema corresponding to as many axioms as there are TY_2 predicates, or equivalently, to take the quantifier $\forall P$ to be substitutional rather than objectual; this would result in a theory that is still first-order.

(9) a. It is not raining.
b. $\exists e.\, actual(e) \wedge e \in Neg(\lambda e'.\, rain(e'))$
c. $\neg \exists e.\, actual(e) \wedge rain(e)$

Formula (9b) states that some anti-rain event is actual. Given the Principle of Negation, this is equivalent to stating that no raining event is actual. That is, given the Principle of Negation, (9b) and (9c) are equivalent.

This technically simple result is of fundamental importance for this paper. In using formula (9b) instead of (9c) as the translation of sentence (9a), we have been able to rely on the *Neg* function instead of complement negation to translate the word *not*, while the Principle of Negation ensures that this makes no difference as far as truth conditions are concerned. Since *Neg*, unlike ¬, modifies event predicates and not formulas, both negative and positive sentences can be taken to describe sets of events.

5 CONSEQUENCES OF THE PRINCIPLE OF NEGATION

Given that we translate linguistic negation using *Neg* rather than classical negation (¬), it is incumbent on us to show that *Neg* accounts for the behavior of linguistic negation insofar as it coincides with classical negation.

We use the term *Classicality* for the fact that for any sentence, either this sentence or its linguistic negation is true, but not both. For example, exactly one of the two following sentences is true.[8]

(10) a. Mary did not eat.
b. Mary ate.

Classicality is also sometimes called Bivalence; however, we reserve the term *Bivalence* for the fact that every sentence is either true or false, but not both. Unlike Classicality, Bivalence thus understood is defined without reference to negation.

On our account, Classicality is a consequence of the Principle of Negation together with the assumption that linguistic negation is translated as event negation *Neg*, while Bivalence is a property of the background logic TY_2 in which our account is couched. One could, if desired, maintain Bivalence while relaxing Classicality by weakening the Principle of Negation. In particular, one could make room for such phenomena as homogeneity or presupposition failure by relaxing No Gaps. Alternatively, one could maintain Classicality while relaxing Bivalence, for example by partializing the background logic as shown in Muskens (1995) or Križ (2015).

In the following, we illustrate two further properties of linguistic negation: Downward-entailingness of Negation and Double Negation Cancellation. These properties follow from the Principle of Negation in (7). In fact, if we take events to be the verifiers of propositional variables in the sense of truthmaker semantics, it is possible to give a more general result (Fine, 2017a; Champollion & Bernard, 2024): For a simple propositional language in which propositional variables and complex formulas are interpreted as sets of events, and in which the interpretation of negation and other connectives conforms to the Principle of Negation and similar principles, the same formulas are valid as on the classical interpretation of propositional logic.

8 In this article, we ignore time and tense. Accordingly, we set aside the possibility that *Mary ate* and *Mary did not eat* could both be true (at different times). We briefly return to this issue in Section 10.5.

Downward-entailingness of Negation is the fact that if the negation of some property P holds of some entity, then the negation of any property P' that is more specific than P holds of that entity as well. For example, *Mary did not eat* entails *Mary did not eat an egg*. In our system, Downward-entailingness of Negation is ensured by the following theorem:

(11) **Downward-entailingness of Negation**
$\forall P \forall P' \subseteq P.\ Instantiated(Neg(P)) \rightarrow Instantiated(Neg(P'))$
(If there is an actual anti-P event, then for any subset P' of P, there is an actual anti-P' event.)

The proof of this theorem uses both directions of the Principle of Negation:

(12) For any two event predicates P and P', such that $P' \subseteq P$:
a. $\exists e \in Neg(P).\ actual(e)$
b. $\Rightarrow \neg[\exists e' \in P.\ actual(e')]$ *(No Gluts on P)*
c. $\Rightarrow \neg[\exists e' \in P'.\ actual(e')]$ *($P' \subseteq P$)*
d. $\Rightarrow \exists e \in Neg(P').\ actual(e)$ *(No Gaps on P')*

Thus, like complement negation, event negation gives rise to downward-entailing environments. This means that theories of negative polarity item licensing that rely on Downward-entailingness of Negation (Ladusaw, 1982) can be implemented equally well no matter if they are based on complement negation or on event negation.
Event negation also validates Double Negation Cancellation. For instance, *Mary ate* and *Mary did not not eat* are predicted to be semantically equivalent (though they may differ in what they convey pragmatically). In our system, Double Negation Cancellation is ensured by the following theorem:

(13) **Double Negation Cancellation**
$\forall P.\ Instantiated(P) \leftrightarrow Instantiated(Neg(Neg(P)))$
(If there is an actual P event, then there is an actual anti-anti-P event, and vice versa.)

The proof of this theorem involves two applications of the Principle of Negation:

(14) For any event predicate P,
a. $\exists e \in P.\ actual(e)$
b. $\Leftrightarrow \neg[\exists e' \in Neg(P).\ actual(e')]$ *(Principle of Negation on P)*
c. $\Leftrightarrow \exists e \in Neg(Neg(P)).\ actual(e)$ *(Principle of Negation on $Neg(P)$)*

One might wonder if the stronger property $\forall P.\ Neg(Neg(P)) = P$ also holds; that is to say, one might wonder if *Neg* is an involution. But this does not follow from the Principle of Negation, and we will not make this assumption. Consider, for example, a three-element model based on the set $S = \{e_1, e_2, e_3\}$ in which only e_1 is actual and, for any $P \subseteq S$, if $e_1 \in P$ then $Neg(P) = \{e_2\}$, else $Neg(P) = \{e_1\}$. Clearly the Principle of Negation holds in this model (this also shows that our Principle is consistent), but *Neg* is not an involution (and not even an injection) since, for example, $Neg(Neg(\{e_3\})) = Neg(\{e_1\}) = \{e_2\}$.

6 ADDING *NEG* TO A MODEL

One might wonder if there are any models that satisfy the Principle of Negation and that look anything like ordinary models of predicate logic with event semantics. Here we show that the answer to these questions is affirmative, by extending a model of event semantics into a model with *Neg* which satisfies the Principle of Negation. This is similar to extending a model of classical predicate logic into a Kripke model of modal predicate logic in the style of Kripke (1963). Simplifying a bit, a Kripke model can be seen as a collection of models of classical predicate logic along with an accessibility relation among them, with one of these models designated as the actual world. One can trivially extend any model of classical predicate logic into a one-world Kripke model by treating the original model as the actual world and by taking the accessibility relation to relate the actual world to itself.

Let $M = (D_e, D_v, I)$ be an extensional model of usual (neo-)Davidsonian event semantics, where D_e is the set of individuals, D_v is the set of events, and I is the interpretation function which interprets the nonlogical symbols of the language. This model interprets a language of two-sorted classical predicate logic which does not include the expressions *actual* and *Neg*, and it cannot be used to interpret nonfinite negated perception reports. Indeed, if, for instance, Mary did not leave, then M describes this fact by not including any leaving event by Mary; but M does not provide the resources that would be needed to describe whether John saw her not leave. Absent any additional information about who saw whom not leave (and similarly for other perception reports with negative complements), it is only possible to define a model with *Neg* that makes a relatively trivial use of negative events; but this is enough to answer the questions at hand.

To define a model with *Neg*, we extend the interpretation I into an interpretation I' for an extended language that includes the predicate *actual* and the *Neg* function. We define $I'(actual) = D_v$; all of the events of M are actual. We define $I'(Neg)$ as the function that maps the empty set to D_v and all nonempty subsets of D_v to the empty set. The following extended model can then be defined: $M' = (D_e, D_v, I')$. M' contains only actual events, and given the interpretation of *Neg*, the Principle of Negation clearly holds in M'.

The construction of the extended model M' from M is truth-preserving in the sense that a formula ϕ is true in M iff the formula ϕ' is true in M', where ϕ' is the translation of ϕ obtained by first replacing subformulas in ϕ of the form $\neg\exists e.\ \psi$ with $\exists e'.\ Neg(\lambda e.\ \psi)$ and then replacing subformulas of the form $\exists e.\ \psi$ with $\exists e.\ actual(e) \wedge \psi$. For instance, $\exists e.\ leave(e) \wedge ag(e) = Mary$ is true in M iff $\exists e.\ actual(e) \wedge leave(e) \wedge ag(e) = Mary$ is true in M', and $\neg\exists e.\ leave(e) \wedge ag(e) = Mary$ is true in M iff $\exists e'.\ actual(e') \wedge e' \in Neg(\lambda e.\ leave(e) \wedge ag(e) = Mary)$ is true in M'.

By construction, the extended model M' as described so far in effect collapses the distinction between complement negation and event negation. As a result, M' cannot yet be used to interpret perception reports with negative complements in a truthful way (see Section 2). To do so, one needs to further modify M' in a way that reflects reality, for example by letting *Neg* map some sets of events to some proper subsets of D_v instead of D_v itself. Since the truth values of perception reports cannot be predicted from the truth values of their complement clauses, this further modification cannot be carried out algorithmically without additional information. Furthermore, it is possible for two models which have been further modified in this way to agree on the interpretation of all symbols other than *Neg* but not on *Neg* itself, and thus to disagree on the truth value of some formulas that include *Neg*. To illustrate, consider the following formula, corresponding to the nonfinite perception report *John sees Mary not leave* (see Section 9):

(15) $\exists e \exists e'.\ actual(e) \wedge see(e) \wedge exp(e) = John \wedge th(e) = e' \wedge$
$e' \in Neg(\lambda e''.\ leave(e'') \wedge ag(e'') = Mary)$

Two extended models may both agree that the set denoted by $Neg(\lambda e''.\ leave(e'') \wedge ag(e'') = Mary)$ contains some actual events and they may yet disagree on whether this set contains any actual events seen by John. More generally, nonfinite perception reports and other constructions that embed event predicates, other than closure operators and the like, are nonextensional environments, in the sense that their truth value is not determined solely by whether the sets of events that they embed are instantiated or not.

Since the extension of *Neg* can vary across models, *Neg* is a nonlogical symbol, like nonlogical determiners such as *most*, *many*, *few* and *a few* in Barwise & Cooper (1981) and similarly to the necessity operator $\Box$ in Kripke (1963). The semantics of $\Box$ is defined in terms of an accessibility relation between worlds which can likewise vary across models. The parallel with modal logic is especially salient when our system is compared to a translation of modal propositional logic into a fragment of first-order logic (van Benthem, 1984, §1). In such a translation, the necessity operator corresponds to a quantifier over worlds whose range is restricted by a relation R, whose interpretation varies across models just like our interpretation of *Neg* does.

7 INTERACTION WITH CONJUNCTION AND DISJUNCTION

We are now in a position to ask how event negation interacts with the other logical connectives. Here we focus on disjunction and conjunction. In the following, P and P' are variables of type $\langle v, t\rangle$, and e, e', e'', etc., are variables of type v. We assume that disjunction of predicates is just set-theoretic union, as is standard in possible world semantics.

(16) **Disjunction of event predicates**
$[\![\text{or}]\!] \stackrel{\text{def}}{=} \lambda P' \lambda P \lambda e.\ P\, e \vee P'\, e$

The case of conjunction is slightly more complex. The common treatment of conjunction in terms of set-theoretic intersection that is familiar from possible world semantics ("intersective conjunction") is not appropriate in a setting where verbs and verb phrases denote event predicates (Lasersohn, 1995). To be sure, it is possible to reconcile intersective conjunction with event semantics by lifting the types of verbal projections to the type of generalized quantifiers (Champollion, 2015). But our *Neg* function applies to event predicates, and so it is natural to adopt an entry for conjunction that applies to event predicates too without the need for type lifting. An appropriate entry is found in exact truthmaker semantics (e.g., Fine, 2017b). It can also be found in a number of places in the linguistic literature (e.g., Krifka, 1990; Lasersohn, 1995; Schubert, 2000; Heycock & Zamparelli, 2005). To this end, we assume that events and individuals each form a complete distributive lattice. The point of this assumption is to ensure that we can sum up or fuse any set of events into an event (and similarly for individuals; in what follows, we focus on the lattice of events). The lattice structure provides us with a partial order $\sqsubseteq$, which we take to represent mereological parthood, and whose least upper bound operator is $\bigsqcup$, which represents mereological sum or fusion. We write "$\bigsqcup P$" for the sum of all the members of a set P; as a special case, we write "$x \sqcup y$" for the sum of x and y (events or individuals). For details on mereology and its linguistic applications, see Champollion & Krifka (2016). Our entry for conjunction is then the following:

(17) **Collective conjunction of event predicates**
$[\![\text{and}]\!] \stackrel{\text{def}}{=} \lambda P' \lambda P \lambda e''.\ \exists e \exists e'.\ [e'' = e \sqcup e' \wedge P\, e \wedge P'\, e']$

This entry combines two event predicates P and P' to an event predicate that holds of the sum of any P event and any P' event. We refer to this treatment of conjunction as *collective conjunction*. For its relationship to intersective conjunction, see also Winter (2001) and Champollion (2016c). Our entries for *not*, *and*, and *or* apply to event predicates only; they can coexist peacefully with other entries that apply to truth values, or in an appropriate setting, to sets of possible worlds.

Since we have assumed event mereology, we need to refine the assumption that events are classified into actual and nonactual. We assume that the property of being actual is transferred both upward from parts to their sums, and downward from events to their parts. More formally, we relate actuality to event mereology by assuming the following principles:

(18) **Distributivity of Actuality Principle**
$\forall e.\ [actual(e) \rightarrow \forall e' \sqsubseteq e.\ actual(e')]$
(Every part of any actual event is itself actual.)

(19) **Cumulativity of Actuality Principle**
$\forall P.\ [\forall e \in P.\ actual(e)] \rightarrow actual(\bigsqcup P)$
(A sum of actual events is itself actual.)

A special case of this second principle is that if e and e' are both actual then so is $e \sqcup e'$.[9] From these principles we can show that event negation obeys the Laws of Excluded Middle and of Noncontradiction. Here we follow van Fraassen (1966) in using the term *Law of Excluded Middle* to refer to the fact that the disjunction of any sentence with its own negation is true. For example, *Either Mary slept or she didn't sleep* is true. Likewise, we use the term *Law of Noncontradiction* for the fact that the negation of the conjunction of any sentence and its own negation is true; for example, *Mary did not both sleep and not sleep* is true.

Our Principle of Negation ensures what we have called Classicality: a negated event predicate is instantiated just in case its prejacent is not. Given this, it follows from the Distributivity and Cumulativity of Actuality Principles that the disjunction of two event predicates is instantiated just in case at least one of its disjuncts is, and that the collective conjunction of two event predicates is instantiated just in case both of its conjuncts are (Champollion & Bernard, 2024).

So there is a clear parallel between our translations of *not*, *and*, and *or* and the truth tables of propositional logic. This also extends to more complex sentences:

(20) a. It didn't rain and snow.
b. $\exists e.\ actual(e) \wedge e \in Neg(\lambda e'.\exists e_1 \exists e_2.\ rain(e_1) \wedge snow(e_2) \wedge e' = e_1 \sqcup e_2)$

(21) a. It didn't rain or it didn't snow.
b. $\exists e.\ actual(e) \wedge [e \in Neg(\lambda e'.\ rain(e')) \vee e \in Neg(\lambda e'.\ snow(e'))]$

In formula (20b), the *Neg* function applies to the output of the collective conjunction, which in turn holds of any sum of a raining event and a snowing event. Suppose that sentence (20a) is true, i.e., that it describes an actual event. It follows that there is either no actual raining event or no actual snowing event (and formula (21b) follows from this).

9 Another special case is that if $P = \emptyset$, $\bigsqcup P$ (the null event, which is part of every event) is actual. We countenance the null event only as a dummy object to which no lexical predicate applies (Link, 1998; Bylinina & Nouwen, 2018). No major consequences would result for our theory if one were to drop the null event.

For suppose otherwise; then some raining event and some snowing event would be actual; by Cumulativity of Actuality, so would their sum; by the entry in (17), this sum would be described by the prejacent of the negation in sentence (20a); by the Principle of Negation, that sentence would not describe any actual event, contrary to assumption. A similar argument applies to disjunction.

From the point of view of propositional logic, this is just part of the familiar behavior of the interaction of conjunction and negation, i.e., de Morgan's Law $\neg(p \wedge q) \Leftrightarrow \neg p \vee \neg q$.[10] The point here is that although event-based negation is nonstandard, it interacts appropriately with the other connectives. Unlike complement negation, however, it delivers negative events.

8 A BASIC COMPOSITIONAL SEMANTIC FRAGMENT

We have seen that the Principle of Negation accounts for the behavior of linguistic negation insofar as it coincides with classical negation. This section develops a small neo-Davidsonian fragment of English based on the model we have introduced. We demonstrate the flexibility of this approach by giving relevant indications about different implementation choices than those we have made here.

The main challenge for a compositional semantic implementation is to ensure that all the relevant information is interpreted in the semantic scope of the *Neg* function. In particular, the assumption that *Neg* is introduced by VP negation requires some attention because, at the surface level, English VP negation (i.e., the word *not*) takes syntactic scope below the subject. But the semantic information conveyed by the subject needs to be accessible to *Neg*, so the semantic scope of *Neg* must include the subject. Consider for example the following sentence:

(22) Mary did not leave.

This sentence cannot be taken as relating Mary to an actual anti-leaving event, as in (23), which would be the expected translation if *Neg* took semantic scope below the subject. This is because anti-leaving events prevent leavings even by agents other than Mary.

(23) **Incorrect translation of *Mary did not leave***
$\exists e.\ actual(e) \wedge ag(e) = Mary \wedge e \in Neg(\lambda e'.\ leave(e'))$
(There is an actual anti-leaving event whose agent is Mary.)

More precisely, suppose (23) is true. Then there is an actual anti-leaving event. It follows via contraposition from No Gaps in (8b) that there are no actual leaving events, whoever their agent may be. The Principle of Negation in (7) relates the actuality of *any* anti-*P* event to the nonactuality of *all P* events; no additional information about an actual anti-*P* event, such as about its agent, can affect the Principle of Negation. In other words, the Principle of Negation is blind to information not contained in *P*. As a result, (23) entails that nobody left.

The problem is that in (23), *Neg* takes scope over a predicate that holds of all leaving events regardless of whether their agent is Mary. Clearly, the only kinds of events that are

10 Each de Morgan's Law states the *equivalence* of two *distinct* formulas; similarly, even though the sets of events described by (20a) and (21a) are either both instantiated or neither of them is, they may well be different. For example, the set of anti-rain-and-snow events might well not be the union of the set of anti-rain events with the set of anti-snow events. This is discussed in more detail in Champollion & Bernard (2024).

precluded by the truth of (22) are leaving events by Mary. Therefore, we take (22) to state that there is an anti-Mary-leaving event that is actual, as in this formula:

(24) **Correct translation of *Mary did not leave***
$\exists e.\ actual(e) \wedge e \in Neg(\lambda e'.\ leave(e') \wedge ag(e') = Mary)$
(There is an actual anti-Mary-leaving event.)

This formula, unlike (23), does not rule out actual departures by people other than Mary. In order to generate formula (24) from sentence (22), we need to resolve the scope mismatch between surface syntax, where *not* takes syntactic scope only over *leave* but not over *Mary*, and semantics, where *Neg* must take scope over $\lambda e.\ leave(e) \wedge ag(e) = Mary$ and thus both over *leave* and over *Mary*.

There is another reason for giving *Neg* semantic scope over the subject and its associated thematic role. This reason can be illustrated with cases of mismatch between the thematic roles of the subjects of antonyms. Consider, for example, the antonyms *leave* and *stay*. Assume that the subject of a leaving event is its agent, while the subject of a staying event is its theme. The incorrect formula in (23) assigns the agent role to a negative event (in this case, to an anti-leaving event). This is problematic if one wishes to ensure compatibility with the view according to which the same event can be described as a staying and as a non-leaving. Suppose that *e* is a staying by Mary. In that case, Mary is the theme of *e*, and *e* has no agent. Thus, *e* could not be described as a non-leaving by Mary if this entailed that the thematic relation between *e* and Mary was the one determined by the verb *leave*, i.e., the agent relation. In general, there is no reason to assume that pairs of antonyms should always assign the same thematic role to their subjects. And pairs of antonyms are just specific cases of the issue. Take an event *e* that falls both under a positive and a negative description (not necessarily involving a pair of antonyms). These two descriptions might well assign different thematic roles to their subjects. For this reason, we conclude that there are clear benefits to giving *Neg* semantic scope over the subject and that the scope mismatch is real.

There are several well-known strategies, both syntactic and semantic, for resolving scope mismatches of this kind. In this paper, we assume that the input to compositional semantic interpretation is the Logical Form (LF) of a sentence, which may differ from its Phonetic Form (PF) (e.g., Chomsky, 1995). We assume that subjects are base-generated within a verbal projection within the scope of negation, and move out of it (Koopman & Sportiche 1991). When negation is present, it applies to this projection and subjects move past it. This verbal projection was identified with VP in Koopman & Sportiche (1991) but more recent versions of this proposal make different assumptions. Although this is not essential to our proposal, we assume in our derivations that this verbal projection is labeled VoiceP, in line with current syntactic assumptions following Kratzer (1996). VoiceP takes a VP as its complement and the verb's external argument as its specifier.

To be sure, it would also be possible to resolve the scope mismatches in a semantic way rather than syntactically, as in Bernard & Champollion (2018).[11] We adopt a syntactic

11 Specifically, Bernard & Champollion (2018) (a precursor to the present paper) is based on the assumption that negation denotes the higher-order function $\lambda V \lambda f \lambda e.\ e \in Neg(\lambda e'.\ V\, f\, e')$. This function takes a verb phrase V and a (continuized) subject f as its arguments, internally combines them, applies the *Neg* function to the result of the combination, and returns the output of *Neg*. This strategy is directly compositional; that is, it does not require a separate level of Logical Form (Jacobson, 2012).

strategy here in order to demonstrate that the applicability of negative events to natural language semantics is not tied to either framework. While it gives up direct compositionality, it keeps the types lower. We leave open whether one could provide a unified framework in which both strategies can be implemented simultaneously, as in Barker (2007).

In this fragment, verbs are interpreted as event predicates:

(25) $[\![\text{leave}]\!] \stackrel{\text{def}}{=} \lambda e.\ \mathit{leave}(e)$

We relate verbs to their arguments and adjuncts via thematic roles like *ag* introduced by silent theta-role heads like [ag] or by prepositions (e.g., Carlson, 1984). Proper names and other noun phrases associate with these items to yield event predicates. Sample translations for these items are shown here:

(26) $[\![\text{Mary}]\!] \stackrel{\text{def}}{=} \mathit{Mary}$

(27) a. $[\![\text{[ag]}]\!] \stackrel{\text{def}}{=} \lambda x \lambda e.\ ag(e) = x$

b. $[\![\text{[th]}]\!] \stackrel{\text{def}}{=} \lambda x \lambda e.\ th(e) = x$

For compatibility with syntactic frameworks, we assume that in ordinary active sentences whose subjects are agents, the category of the [ag] role head is Voice. One could, alternatively, just as well treat thematic role heads as akin to silent prepositions, as in Champollion (2016b).

Kratzer (1996) assumes that the translation of the Voice head in (27a) combines with the VP and the specifier to form an event predicate, via a rule she calls Event Identification (EI). Here we generalize EI to a type-shifter that allows thematic role heads to combine with verbal projections via function application. In general, let $[\theta]$ be any thematic role head of type $\langle e, \langle v, t \rangle\rangle$, such as [ag] or [th]. Then the EI-shifted version of this head, $[\theta]$', can be obtained from the following schema:

(28) **Event Identification type-shifter**

$\lambda V \lambda x \lambda e.\ [\![[\theta]]\!]\, x\, e \wedge V\, e$

For example, the EI-shifted version of the agent role, [ag]', is translated as follows:

(29) $[\![\text{[ag]'}]\!] \stackrel{\text{def}}{=} \lambda V \lambda x \lambda e.\ ag(e) = x \wedge V\, e$

We now turn to the heart of our proposal. For concreteness and compatibility, we treat the word *not* as a syntactic head whose category is a functional projection which we also label *Neg* (Emonds, 1976; Pollock, 1989). This head lacks a specifier and takes as its complement a verbal projection such as VoiceP which contains the verb and all of its syntactic arguments. The word *not* is translated using the *Neg* function:

(30) $[\![\text{not}]\!] \stackrel{\text{def}}{=} \lambda V \lambda e.\ e \in \mathit{Neg}(V)$

This expression is eta-equivalent to just *Neg*, but we keep the lambda slots for clarity. The expressions presented so far form the basis of our fragment; more expressions are introduced below.

An important choice arises at the root node of each derivation, depending on one's views about what sentences denote. The account that we develop in this paper is consistent with a range of frameworks. These include: (i) extensional semantics, in which the denotation of a sentence is its truth value; (ii) intensional possible world semantics, in which sentences denote sets of those possible worlds at which they are true; and (iii) the hyperintensional truthmaker semantics in Fine (2017a) and Champollion & Bernard (2024), where sentences denote sets of events or "verifiers", and where asserting a sentence amounts to asserting that its denotation contains an event or verifier that is actual. By default, our derivations deliver sets of events, and this makes option (iii) the most natural choice. This view is also the only one that is compatible with truthmaker maximalism, or the doctrine that every true sentence has a verifier. Options (i) and (ii) can be implemented by assuming that an appropriate operator applies that shifts sets of events to truth values or to sets of possible worlds. In what follows, we adopt option (i). To this end, we introduce the following existential closure operator:

(31) $\mathit{closure} \stackrel{\text{def}}{=} \lambda V.\ \exists e.\ \mathit{actual}(e) \wedge V\, e$

This operator is standard in event semantics, except for its explicit restriction to events that are actual. If it is taken to be part of the semantics (rather than the pragmatics), a further question is whether it can also appear in embedded environments. We assume that it cannot, so we do not permit movement above it. For concreteness, in our derivations we display it at the root node. But closure can in principle be dispensed with as a semantic operator without affecting the view on negation we advance here. The only role of closure in our system is to convert sets of events to truth values.

To recapitulate our assumptions about the syntax-semantics interface, here is a sample derivation:

(32) a. Mary did not leave.
b. [closure [[$_{DP}$ Mary] [1 [$_{TP}$ (did) [$_{NegP}$ not [$_{VoiceP}$ t_1 [ag' leave]]]]]]]
c. $\exists e.\ \mathit{actual}(e) \wedge e \in \mathit{Neg}(\lambda e'.\ \mathit{ag}(e') = \mathit{Mary} \wedge \mathit{leave}(e'))$

Figure 1 shows this derivation in more detail; it illustrates the VP-internal subject hypothesis and movement of the subject out of VoiceP (in this sentence, the subject is of type *e*, so the movement is semantically vacuous). Since we ignore the contribution of tense, we omit words like *did* and tense morphemes. Our semantic composition rules are standard: we use function application and predicate abstraction (Heim & Kratzer, 1998). Predicate abstraction is triggered by variable binders that are introduced by movement; traces (or lower copies) are indicated by angle brackets and translate to variables like t_1 bound by variable binders like "1".

Entries for conjunction and disjunction of verbal projections as discussed in Section 7 can be formulated straightforwardly:

(33) a. $[\![\text{and}]\!] \stackrel{\text{def}}{=} \lambda V_2 \lambda V_1 \lambda e.\ \exists e_1 \exists e_2.\ e = e_1 \sqcup e_2 \wedge V_1(e_1) \wedge V_2(e_2)$
b. $[\![\text{or}]\!] \stackrel{\text{def}}{=} \lambda V_2 \lambda V_1 \lambda e.\ V_1(e) \vee V_2(e)$

As desired, these entries can apply in equal measure to negated and nonnegated verbal projections.

We now present a brief sketch of the quantifiers *some student*, *no student*, and *every student*. We defer a full discussion of these and other similar constructions to future work.

(34) a. $[\![\text{some student}]\!] \stackrel{\text{def}}{=} \lambda R \lambda e.\ \exists x.\ \mathit{student}(x) \wedge R\, x\, e$
b. $[\![\text{no student}]\!] \stackrel{\text{def}}{=} \lambda R \lambda e.\ e \in \mathit{Neg}(\lambda e'.\ \exists x.\ \mathit{student}(x) \wedge R\, x\, e')$
c. $[\![\text{every student}]\!] \stackrel{\text{def}}{=} \lambda R \lambda e.\ e \in \mathit{Neg}(\lambda e'.\ \exists x.\ \mathit{student}(x) \wedge e' \in \mathit{Neg}(\lambda e''.\ R\, x\, e''))$

The relation *R* can be obtained by predicate abstraction from within a verbal projection. The entry in (34b) can be decomposed into $[\![\text{no}]\!]$ and $[\![\text{student}]\!]$ or gained composition-

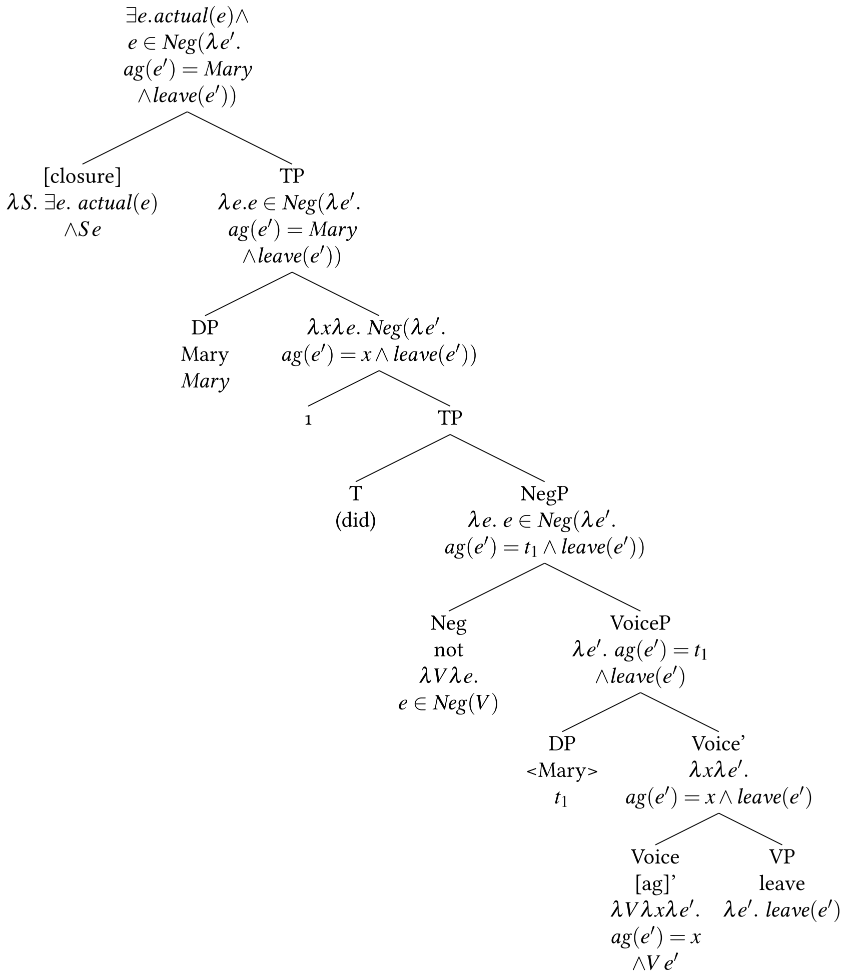

Figure 1 A sample derivation of *Mary did not leave*.

ally from the semantics of *not* and *some student*, in the sense that $[\![\text{no student}]\!] = \lambda R.\ [\![\text{not}]\!]([\![\text{some student}]\!]\ R)$.[12] Accordingly, in (34b), the *Neg* function takes scope over the existential quantifier over individuals. Similarly, the entry for *every student* in (34c) is obtained from the entry for *some student* in (34a) by sandwiching a universal quantifier between two instances of *Neg*, just like the universal quantifier $\forall$ can be defined as $\neg\exists\neg$ in first-order logic.

12 This is appropriate for languages that lack negative concord. One possible approach to negative concord, as in Zeijlstra (2007), is to omit *Neg* from the semantics of the negative quantifier and assume that it is supplied by an overt or covert sentential element.

Here are formulas for three sentences involving these quantifiers:

(35) a. Some student did not eat any cookie.
b. $\exists e.\ actual(e) \wedge \exists x.\ student(x) \wedge e \in Neg(\lambda e'.\ ag(e') = x \wedge \exists y.\ cookie(y) \wedge th(e') = y \wedge eat(e))$

(36) a. No student ate any cookie.
b. $\exists e.\ actual(e) \wedge e \in Neg(\lambda e'.\ \exists x.\ student(x) \wedge ag(e') = x \wedge \exists y.\ cookie(y) \wedge th(e') = y \wedge eat(e'))$

(37) a. Every student ate a cookie.
b. $\exists e.\ actual(e) \wedge e \in Neg[\lambda e'.\ \exists x.\ student(x) \wedge e' \in Neg(\lambda e''.\ ag(e'') = x \wedge \exists y.\ cookie(y) \wedge th(e'') = y \wedge eat(e''))]$

In the following section, we put the framework to use in the construction that has served to motivate event negation in Section 2: nonfinite perception reports.

9 CASE STUDY: NONFINITE PERCEPTION REPORTS

Perception reports involve verbs of perception like *see* or *hear* and clausal complements that are either nonfinite or finite. Nonfinite complements of perception reports are also sometimes called naked or bare infinitives. Nonfinite perception reports are illustrated in (38a) and finite perception reports in (38b).

(38) a. John {saw/heard} Mary play a sonata.
b. John {saw/heard} that Mary played a sonata.

The main generalizations about perception reports were laid out by Barwise (1981): Nonfinite perception reports entail that the perceiver has direct perceptual evidence for the truth of the complement, while finite perception reports are also compatible with indirect evidence but are accompanied by some sort of understanding on the part of the perceiver. For example, the nonfinite perception report in (38a), unlike the finite one in (38b), entails that John had direct visual or auditory evidence of Mary's playing music but is compatible with John being ignorant about what type of piece Mary played. This section focuses on nonfinite perception reports and labels the relevant predicate as see_{nonfin}; as for finite perception reports, they are best analyzed in an intensional framework, similarly to belief or knowledge reports.

While the first formal analyses of perception reports used situation semantics (Barwise, 1981; Barwise & Perry, 1983), event semantic analyses quickly followed (Higginbotham, 1983; Parsons, 1990; Vlach, 1983; see also Neale, 1988). Here we follow this line of work and treat perception verbs with nonfinite complements as involving a perceived event and an individual who physically perceives it. For compatibility with the overall framework, we also postulate a perceiving event.

In Higginbotham's analysis, sentence (39a) is analyzed using existential quantification over events, as in (39b) (see Higginbotham, 1983, p. 107):

(39) a. John sees Mary leave.
b. [$\exists x$: x is an event & leave(Mary, x)] John sees x.

In the notation of the present paper, we recast this analysis as follows:

(40) $\exists e.\ actual(e) \wedge exp(e) = John \wedge see_{nonfin}(e) \wedge \exists e'.\ th_{event}(e) = e' \wedge ag(e') = Mary \wedge leave(e')$

This formula states that there is an actual seeing event whose experiencer is John and whose theme is a leaving event whose agent is Mary. As motivated in the literature cited above, a key point of this analysis is that a perception report existentially quantifies over two events, of which one is the perceiving event and the other is the perceived event, i.e., the theme of the perceiving event. To avoid type clashes with the ordinary theme function from events to individuals, we use the dedicated symbol th_{event} for the function from perceiving events to perceived events.

We incorporate this analysis into our fragment via the following entry for the variant of the verb *see* that takes nonfinite complements:

(41) $[\![\text{see}_{nonfin}]\!] \stackrel{\text{def}}{=} \lambda V \lambda e.\ see_{nonfin}(e) \wedge \exists e'.\ th_{event}(e) = e' \wedge V\, e'$

Based on this entry, formula (40) is the translation of the following LF (here exp' is the shifted experiencer role and is denoted by the Voice head instead of ag'):

(42) [closure [John [1 [t_1 [exp' [see$_{nonfin}$ [Mary [1 [t_1 [ag' leave]]]]]]]]]

Formula (40) does not state that the leaving event is actual, only that the seeing event is. Arguably, this is as it should be, since for all we know John might be hallucinating. In contexts where this possibility is excluded, however, one may wish to impose the following principle (Barwise, 1981; Schein, 2020):

(43) **Perceptual Veridicality Principle**
$\forall e.\ [actual(e) \wedge see_{nonfin}(e)] \rightarrow actual(th_{event}(e))$
(The theme of any actual seeing event is itself actual.)

With this background in place, let us see how our theory of negative events helps solve the problem of negative perception reports. As we have noted in Section 2, Higginbotham observes that his analysis of perception reports does not extend to negative perception reports if linguistic negation is taken to contribute what we have called complement negation, that is, the standard semantics of $\neg$. However, we assume that linguistic negation in perception reports contributes the *Neg* function. This allows us to maintain the denotation of the nonfinite complement of *see* as an event predicate, even when this complement contains negation. For instance, the nonfinite complement of (44a) has the same LF and denotation as its finite counterpart in Figure 1, except that it does not contain a closure operator and that its T node (which we treat as semantically vacuous anyway) indicates nonfiniteness rather than past tense. This gives us the following LF and denotation:

(44) a. I saw Mary not leave.
b. [closure [I [1 [t_1 [exp' [see$_{nonfin}$ [Mary [1 [not [t_1 [ag' leave]]]]]]]]]]
c. $\exists e.\ actual(e) \wedge exp(e) = I \wedge see_{nonfin}(e) \wedge$
$\exists e'.\ th_{event}(e) = e' \wedge e' \in Neg(\lambda e''.\ ag(e'') = Mary \wedge leave(e''))$

This formula states that there is an anti-Mary-leaving event that the speaker actually saw. Given the Perceptual Veridicality Principle in (43), it follows that the anti-Mary-leaving event e' in (44c) is actual. Given this, the Principle of Negation then ensures that no leaving event by Mary is actual. That is to say, Mary did not leave. This is as it should be: it is not enough for the event seen by the speaker to be something other than a leaving event by Mary, the event must also positively ensure that no such leaving event occurred. In this way we see that the truth conditions we predict are appropriately strong.

Our analysis is a straightforward application of our theory of negation. The same event negation is operative in embedded negated perception reports and in ordinary unembedded negated sentences. This unified approach to negation might seem to be in tension with the common observation that negative events are intuitively associated with "the breaking of a habitual or expected pattern of activity" (Stockwell *et al.*, 1973, pp. 250–251; concurring, Horn, 1989, pp. 51–55; for similar observations, see Higginbotham, 1983, note 15, pp. 111–112 and de Swart, 1996, §2.2). Our approach does not predict a difference between embedded and ordinary negation in this respect and does not attribute the breaking of a pattern of activity to the semantics of negation.

However, this unexpectedness inference is defeasible and should therefore be attributed to the pragmatics rather than the semantics of negation (e.g., Neale, 1988). In any case, these inferences do not pose a problem for a unified approach to negation, since analogous observations have been made for unembedded negative sentences. In a recent review of the pragmatic literature, Tian & Breheny (2019, §12.4) observe that negated sentences often require certain kinds of supporting contexts to be appropriate. Sentences like *Mary did not smoke* and *The car did not start*, for instance, do not seem natural in contexts in which Mary was not expected to smoke and the car was not expected to start. Likewise, as Tian & Breheny note, in a street with many small hotels, a sign on a house saying 'This is not a hotel' gives rise to the inference that many people have mistakenly expected this house to be a hotel. So the unexpectedness inference is common to unembedded and embedded negation.

So far, we have presented a notion of negative events and formalized it in a model-theoretic semantics. This semantics is based on a standard logic and relies mainly on a notion of actuality and a function *Neg* that yields events which are interpreted as negative thanks to the Principle of Negation. We have then shown that the semantics of the *Neg* function can be embedded into a fragment of English which handles negated nonfinite perception reports. The remainder of this paper compares our approach with selected previous work on negation in event semantics.

10 PREVIOUS WORK

There are two reasons that make it difficult to account for negation in event semantics. The first reason is a type mismatch: the input type of classical negation does not match the types that event semantics ordinarily assigns to verbal denotations. This mismatch also applies to other operators and is a special case of what Winter & Zwarts (2011) dubbed the "Event Quantification Problem". The second reason is that any operation that flips truth values or maps sets to their complements (i.e., standard complement negation) is ill-suited to model negative descriptions of events.

In Section 10.1 we review compositional event-based frameworks that solve the type mismatch and interpret linguistic negation as complement negation. In Sections 10.2 through 10.3, we discuss previous work by authors who, like us, have adopted a nonstandard formalization of negation in event semantics. We then critically review, in Section 10.4, the literature that defends analyses in terms of complement negation even in cases such as negative perception reports or negative causation. Section 10.5 discusses an approach that takes negation to involve contextually restricted quantification over subevents of a framing event. Finally, Section 10.6 discusses work whose formalization could potentially benefit from using the *Neg* function introduced in this paper.

10.1 *Complement negation in compositional semantics*

Within approaches to event semantics that analyze linguistic negation as complement negation, a negated sentence expresses the absence of any event described by the prejacent of the negation, and does not introduce "negative" events in any sense of the term.

To address the Event Quantification Problem, some authors do not assume that the prejacents of linguistic negation denote sets of events. This is the case for the approach where complement negation takes scope over an existential quantifier over events, which we have described in Section 2 as "deflationism" (Payton, 2021). For example, Champollion (2015) includes an existential quantifier over events within the lexical entries of verbs and interprets verbal projections from the verb up to the sentence level as generalized quantifiers over events (type $\langle\langle v,t\rangle,t\rangle$), rather than as sets of events (type $\langle v,t\rangle$). Then, the semantics of linguistic negation and quantifiers can be straightforwardly defined in terms of their familiar logical counterparts.

A conceptually related solution is found in Kamp & Reyle (1993, §5.2.5). In their framework, a sentence is converted into a semantic representation (a Discourse Representation Structure, or "DRS") through iterative transformations of its syntactic structure; this DRS can then be translated into first-order logic. To ensure that negation takes scope above the event quantifier in the first-order logic translation, Kamp & Reyle introduce event variables only after the corresponding verb has been processed, which in turn takes place after negation has been processed.

Another variant of this approach is found in de Groote & Winter (2015). Verbal projections are assigned different types: lower types deal with sets of events and higher types deal with truth values. Logical operators such as negation apply only to higher types. An existential closure operator bridges the two types by the introduction of an existential quantifier over events.

The key of this general strategy lies in formalizing how the grammar introduces the existential closure operator at the desired position. This does not solve the problems addressed in the present paper.

10.2 *Krifka's maximal events*

Krifka (1989) provides a wide-ranging treatment of various phenomena in algebraic semantics. One of his goals is to account for the ambiguity of negation and aspectual adverbials (Smith, 1975):

(45) Mary did not laugh for two hours.
  a. For two hours, it was not the case that Mary laughed.
  b. It is not the case that for two hours Mary laughed.

Krifka analyzes this phenomenon as a scope ambiguity. Motivated by independent concerns related to atelicity, he treats *for two hours* as a modifier of event predicates. Given this, he needs to let both *Mary laughed* and *Mary did not laugh* denote event predicates. This in turn requires him to treat negation as a modifier of event predicates, as on our account. 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 function τ, which sends events to their runtimes, and on the subinterval relation $\sqsubseteq_T$ between time intervals:

(46) $\forall e.\, \mathbf{MXE}(e) \leftrightarrow (\exists t.\, e = \bigsqcup(\lambda e.\, \tau(e) \sqsubseteq_T t))$

(An event is maximal if and only if it is the sum of all the events which occur within some time interval.)

For Krifka, the negation of an event predicate P expresses that some maximal event does not contain any P event:

(47) $[\![\text{not}]\!]_{Krifka} = \lambda P \lambda e.\ \mathbf{MXE}(e) \wedge \neg\exists e'.\ (P\, e' \wedge e' \sqsubseteq e)$

On this approach, *Mary did not laugh* denotes a predicate that holds of any maximal event that corresponds to some time interval within which Mary did not laugh.
In addition to the treatment of aspectual adverbials, Krifka's maximal events have been used in modeling the temporal structure of discourse with and without negation (de Swart & Molendijk, 1999). However, their resemblance with negative events is only superficial (Champollion, 2015, §3); by definition, a maximal event is the sum of all events which occur within some time interval and thus cannot be used to represent any single event that did or did not occur during this interval. As a result, Krifka's (1989) analysis cannot be extended to negative perception reports (nor was it developed for that purpose). For example, consider the following negative perception report:

(48) John saw Mary not laugh.

If we analyzed the embedded *Mary not laugh* along the lines of Krifka's proposal for negation, this sentence would entail that John saw the sum of everything that took place within some interval within which Mary did not laugh. Likewise, this analysis cannot distinguish between cotemporal negative events. Under the same analysis and assuming that some time interval contains no event of Mary laughing and no event of Bill crying, sentence (48) is predicted to entail *John saw Bill not cry*.

10.3 *Antonymic predicates and anti-extensions*

Within the context of an account of perception reports, Higginbotham (1983) suggests that in some cases negation combines with a predicate P to form a "not-P" event predicate. This is motivated by the similarity between (49a) and (49b):

(49) a. John saw Mary not leave.
b. John saw Mary stay.

Higginbotham (1983) credits Judith Thomson with the generalization that such pairs of sentences are equivalent whenever the relevant verbs are antonyms. Elaborating on this idea, Higginbotham (2000) proposes that the relation between predicates P (such as *leave*) and their negated forms $\overline{P}$ (such as *not leave*) obeys the following axiom (where $\circ$ denotes mereological overlap):[13]

13 It is sometimes implied that Higginbotham interprets negation in nonfinite perception reports as related to refraining actions (e.g., van der Does, 1991, p. 250). This is not the case, as Higginbotham indicates with an observation he credits to Stanley Peters: "one can sometimes say things like 'I saw NP not VP' merely to report a circumstance in which one might have expected NP to VP, and where VP has no natural antonym" (Higginbotham, 1983, note 15, pp. 111–112). The fact that Higginbotham's conception of negative events and predicates is not limited to refraining actions also emerges from Higginbotham (2000), based on such examples as *the nonexplosion of the gases* or *the nonrising of the sun*. These examples do not seem to involve any refraining actions.

(50) $\forall t.\ (\neg\exists e.\ (\tau(e) \circ t \wedge P(e)) \rightarrow (\exists e'.\ \overline{P}(e') \wedge \tau(e') = t)$
(If no P event starts or ends anytime during t, then there is a $\overline{P}$ event whose runtime is t.)

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

Higginbotham assumes that overt negation may express the function from P to $\overline{P}$, but does not pursue this further. Unlike the Principle of Negation that we have adopted, axiom (50) is not a biconditional. Therefore, it allows P events and $\overline{P}$ events to cooccur. This fails to rule out models that contain both a Mary-leaving and a Mary-not-leaving event, though this could easily be fixed as on our account. (For further critical discussion of Higginbotham's proposal, see Neale, 1988, and Miller, 2003.) Our own proposal is in the spirit of Higginbotham (2000) and improves on it by strengthening the axiom to a biconditional and embedding event negation into a compositional fragment.

An account of nonfinite perception reports reminiscient of Higginbotham's but that does not use events can be found in van der Does (1991). The basic idea is that each verb translates to two predicates P and $\neg P$ of equal arity and disjoint interpretations (see e.g., Schwarzschild, 1994; Fine, 2017b). Despite appearances, $\neg P$ is a single symbol and not a compound (van der Does, 1991, p. 257). He then defines a nonstandard logic centered around nonfinite perception reports which relies on a logical constant *SEE*. Roughly, for every observer, Does defines a "submodel" that eliminates certain individuals from the interpretations of predicate and relation symbols. A formula like $SEE(John, sleep(Mary))$ is then true just in case $sleep(Mary)$ is true in the submodel associated with John. Similarly, $SEE(John, [\neg sleep](Mary))$ is true just in case $[\neg sleep](Mary)$ is true in John's submodel. Since the symbols *sleep* and $\neg$*sleep* have disjoint interpretations, this can only be the case if John did not see Mary sleep.

A third proposal that is conceptually related to antonymic predicates is developed in Schubert (2000). This paper develops a version of situation semantics (Barwise & Perry, 1983; Muskens, 1995) in which one can describe a situation as characterized by a proposition the same way that a Davidsonian event can be characterized by a predicate such as *run* or *eat*. These characterizing propositions can be denoted by syntactically complex formulas, including negated formulas.

The characterizing operator $**$ relates a situation to a *situation abstract*, which is a logical expression that is syntactically built like a formula except that some of the situation arguments of the basic predicates can be left out. For example, Schubert assumes that both *run* and *eat* have situation arguments, as shown in (51a); the expression in (51b) leaves out these arguments and is thus a situation abstract.

(51) a. $\neg run(s, Mary) \wedge eat(s, John, the\_cake)$
b. $\neg run(Mary) \wedge eat(John, the\_cake)$

Given a situation abstract ϕ and a situation e, the formula $(\phi ** e)$ is interpreted as stating that e is *described* or *characterized* by ϕ; that is, e is a ϕ-event, or as Fine (2017b) would put it, e is an exact truthmaker of ϕ.

Schubert adopts a collective analysis of conjunction and a union-based analysis of disjunction similar to what we have done in Section 7; however, his treatment of negation makes use of disjoint extensions and anti-extensions similar to the ones in van der Does's (1991) system. In effect, he defines negated predicates in terms of the anti-extension of atomic relation symbols between events and individuals. By contrast, in our system, the function *Neg* applies to event predicates of arbitrary complexity, and is not defined directly in terms of the components of these predicates.

The system in Schubert (2000) is set up in such a way that negation distributes over other connectives. In particular, the following is a theorem in his system:[14]

(52) $(\neg(\phi \wedge \psi)) ** e \leftrightarrow (\neg\phi \vee \neg\psi) ** e \leftrightarrow [(\neg\phi) ** e] \vee [(\neg\psi) ** e]$

This theorem is essentially one of de Morgan's Laws at the level of characterizing formulas. This is very different from the behavior of our *Neg* function, which does not validate the corresponding formula $e \in Neg(\lambda e'.\, P\,e' \wedge Q\,e') \leftrightarrow [e \in Neg(\lambda e'.\, P\,e')] \vee [e \in Neg(\lambda e'.\, Q\,e')]$ (see footnote 10 and Champollion & Bernard, 2024).

As a consequence of (52), event modifiers cannot be used by Schubert (2000) in the characterization of events in the way we have used them. Consider sentence (53a). In our system, this is translated as (53b), the set of anti-raining-in-France events.

(53) a. It is not raining in France.
b. $\lambda e.\, e \in Neg(\lambda e'.\, rain(e') \wedge in(e', France))$

Assuming that *rain* takes no location argument, this expression has no exact counterpart in Schubert's (2000) system.[15] Theorem (52) shows that formula (54a) below is equivalent to (54b), which holds of any event that can be characterized *either* as not raining *or* as not being in France.

(54) a. $(\neg(rain \wedge in(France))) ** e$
b. $[(\neg rain) ** e] \vee [(\neg(in(France)) ** e]$

This shows that formula (54a), in contrast to (53b), cannot be used to model the meaning of sentence (53a).

The following formula is not an viable option either:

(55) $(\neg rain) ** e \wedge in(e, France)$

This is because according to this formula, even though e is located in France, its occurrence is incompatible with the occurrence of any raining event (with a runtime overlapping the runtime of e), independently of its location.

Another consequence of the fact that negation distributes over other connectives is that this system cannot be straightforwardly extended to a neo-Davidsonian setting, where verbs denote one-place predicates of events. That is to say, if one had $(run \wedge ag(Mary)) ** e$, then e would be the sum of some e_1 and e_2 such that $run ** e_1$ (a running event) and $ag(Mary) ** e_2$ (a being-done-by-Mary event).

10.4 *Defenses of complement negation*

It has been argued that when negation is involved in a description of events, its semantics is simply complement negation, resulting in weak truth conditions (Miller, 2003; Varzi, 2006;

14 This theorem is a combination of $(\neg\wedge)^{**}$ on p. 428 and $(\vee)^{**}$ on p. 426 of Schubert (2000).

15 If *rain* were to take a location argument, then (53a) could be modeled with the help of the formula $(\neg rain(France)) ** e$.

Schaffer, 2012). On this view, negated sentences contain very underspecified event descriptions of the form $\lambda e.\ \neg(P\,e)$; if a sentence like *John saw Mary not leave* is true, then John saw some event that can be described by the clause *Mary not leave*, and this can be any eventuality that is not an event of Mary leaving. As we have seen in Section 2, this view does not readily account for the contradiction between *John saw Mary not leave* and *Mary left*. To account for this contradiction, some pragmatic strengthening process such as contextual domain restriction is usually invoked but not formalized.

Varzi (2006) defends a version of this view that goes beyond explicit uses of negation. In particular, he does not recognize failure events or omission events, and he claims that definite event descriptions built around words such as *failure* and *omission* only refer when they can be paraphrased. For example, on Varzi's view, in situations where Al did not even try to turn off the gas, the subject of (56) has no referent and the sentence is not true.

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

This raises the question of why (56) can be felicitously used. In fact, if Al did not try to turn off the gas, sentence (56) can be alternatively true, false and undefined. Imagine that Al turned on the gas, subsequently forgot to turn it off when he left, and that an explosion ensued shortly after. Sentence (56) is then intuitively judged true. If, however, no explosion ensued (say, because the window was opened), the sentence is judged false. Only in case Al had no business whatsoever with the gas does a presupposition failure arise. These distinctions cannot be captured on Varzi's (2006) view, according to which in all three cases, *Al's failure to turn off the gas* lacks a referent, leading to a presupposition failure.[16]

A related view is endorsed by Moore (2009) as part of an argument that omissions and preventions are causally inert. According to Moore, sentences that are ostensibly about omission or prevention events are interpreted in terms of negative existentials ($\neg\exists e.\ \ldots e \ldots$). Moore (2009) applies this view to a wide range of predicates including *surviving* (not dying), *starving* (not eating) and *keeping of the secret* (not telling the secret). To the extent that Varzi's (2006) view extends to these predicates too, it would predict that many sentences that are intuitively judged to be true are in fact false or devoid of a classical truth value.

10.5 *Schein (2020): Negation as contextually restricted quantification*

Schein (2020) claims that logical forms contain multiple references to contextually or explicitly specified *spatiotemporal framing events*, or "frames" for short. The complements of perception verbs like *see* and *feel* are analyzed as referring to certain maximal events local to the relevant frame, or as we will put it, events in the frame. These events are maximal with

16 Varzi uses the term "negative event" as we do except that he also extends it to events described by predicates involving failure or omission. When Varzi states that "the only events to be seriously countenanced are the positive ones—those that feature in the actual history of the world", he runs together the distinction between negative and positive events with the actual/nonactual distinction. But these distinctions clearly cross-cut each other. When Al does not turn off the gas, for example, the nonactual events are Al's turnings off of the gas. But the event described as not turning off the gas is actual.

respect to a property specified by the complement; thus *John saw Mary leave* is analyzed, roughly, as *Given that Mary left, John saw the maximal leaving by Mary in the frame*.

Building on his earlier work in Schein (2016), Schein (2020) argues that *not* is an adverb of quantification. The range of meanings of negation is attributed to variation in its scope and antecedent. Verbal and nominal negation are seen as part of a paradigm that includes other downward-entailing adverbial and adnominal quantifiers. Like *never* or *rarely*, *not* is restricted to the subevents of a frame, as in the case of *In flight for two hours, it was* { *not / never / rarely* } *calm*.

According to Schein (2020), there are two canonical forms for negated sentences:

(57) a. $[\exists E : \Phi[E]]\,[No\ e.\ E\,e]\,\Psi(e)$
(≈ Some Φ event contains no Ψ event.)
b. $[\iota E : \Phi[E]]\,[No\ e.\ E\,e]\,\Psi(e)$
(≈ The sum of all Φ events E is a Φ event and contains no Ψ event.)

Here, E is a higher-order event variable; Φ is a higher-order event predicate; and Ψ is a first-order event predicate. For purposes of presentation, we will transpose this theory into the mereological setting. Setting aside certain issues relating to the null event, we can think of E as ranging over sum events; and since sum events are just events, we can think of Φ as an event predicate just like Ψ. *No* is just the negative existential quantifier $\neg\exists$; so $No\ e.\ E\,e$ translates into our framework as $\neg\exists e.\ e \sqsubseteq E$. In general, the restriction of the quantifier *No* is determined by its scope in the sentence and by the frame, which is taken to be the antecedent of a typically silent anaphoric element akin to the words *then* and *there*.

The maximum quantifier $[\iota E : A]\,B$ assigns to E a maximal value such that A is true, and then checks whether B is true. If we think of E as ranging over sums of events, and of A and B as event predicates, then $[\iota E : A]\,B$ says that the sum of all As is both an A and a B. When A is cumulative, as in what follows, we can express this by saying that the sum of all As is a B, or more simply, that the As are B.[17] The variant $[\iota E : C.\ A]\,B$ of the maximum quantifier, which appears in example (156) in Schein (2020) and in the formulas below, adds C as a further condition, which Schein calls an "appositive modification"; following Schein, we gloss $C.A$ as *given that* C, A (for details see Schein, 2006, §29.2.2, and Schein 2019, §7).

The following formulas illustrate the application of the theory in Schein (2020) to a selection of simple sentences. Each formula is followed by a paraphrase of how it can be read in mereological terms. The more complex formulas contain variants of the simpler formulas, so it is helpful to step through them in order of complexity. Throughout these formulas, E is the spatiotemporal frame.[18]

(58) a. Mary left.
b. $[\iota E : \mathit{then\&there}[E]][\exists E_1 : \mathit{local}[E_1, E]](\mathit{leave}[E_1] \wedge Ag[\mathit{mary}, E_1])$
c. There is a leaving event E_1 by Mary in the frame.

(59) a. Mary did not leave.
b. $[\iota E : \mathit{then\&there}[E]][\iota E_2 : \mathit{local}[E_2, E]][No\ e : E_2\ e](\mathit{leave}[e] \wedge Ag[\mathit{mary}, e])$
c. With E_2 the events in the frame, no part of E_2 is a leaving by Mary.

17 The ι quantifier is further discussed in Schein (2016) and Schein (2019); the latter also considers a more complicated definition of ι in terms of overlap. The two definitions are equivalent when A is divisive, as is the case in the examples that we are about to consider.

18 We thank B. Schein (p.c.) for providing and discussing these formulas.

(60) a. John saw Mary leave.

b. $[\iota E : \mathit{then\&there}[E]]$

$[\iota E_1 : \mathit{True}(`[\exists E_1 : \mathit{local}[E_1, E]](\mathit{leave}[E_1] \wedge \mathit{Ag}[\mathit{mary}, E_1])').$

$(\mathit{local}[E_1, E] \wedge \mathit{leave}[E_1] \wedge \mathit{Ag}[\mathit{mary}, E_1])]$

$[\exists E_0 : \mathit{local}_{\text{past}}[E_0, E]](\mathit{see}[E_0, E_1] \wedge \mathit{Exp}[\mathit{john}, E_0])$

c. Given that "Mary left" is true in the frame, with E_1 the leaving by Mary in the frame, John sees E_1 in an event E_0 local_{past} to the frame.

(61) a. John saw Mary not leave.

b. $[\iota E : \mathit{then\&there}[E]]$

$[\iota E_2 : \mathit{True}(`[\iota E_2 : \mathit{local}[E_2, E]][\mathit{No}\ e : E_2\ e](\mathit{leave}[e] \wedge \mathit{Ag}[\mathit{mary}, e])').$

$(\mathit{local}[E_2, E] \wedge [\mathit{No}\ e.\ E_2\ e](\mathit{leave}[e] \wedge \mathit{Ag}[\mathit{mary}, e])]$

$[\exists E_3 : \mathit{local}_{\text{past}}[E, E_3]](\mathit{see}[E_3, E_2] \wedge \mathit{Exp}[\mathit{john}, E_3])$

c. Given that "Mary did not leave" is true in the frame, with E_2 the events in the frame which do not contain leaving events by Mary, John sees E_2 in an event E_3 that is local_{past} to the frame.[19]

In essence, (61b) amounts to the following: Mary did not leave in the frame, and John sees the maximal event in the frame that does not contain a leaving by Mary. But this is just a roundabout way of saying the following: Mary did not leave in the frame and John saw the maximal event in the frame.

These truth conditions are either too strict or too lenient, depending on whether we assume that John sees the maximal event in the frame only if he sees each event in the frame. If we make this assumption, then (61b) will incorrectly come out as false whenever there is some event in the frame that John happens not to see, even if he sees a staying event by Mary in the frame. This issue is similar to the problem pointed out in Section 10.2 for Krifka's proposal for negation, except that this time the maximal events contain everything in some frame rather than everything within some time interval. Conversely, we might assume that John can see the maximal event E_2 by seeing any event in E_2, just as one can see a storm by seeing any part of that storm. In that case, (61b) will incorrectly come out as true whenever Mary did not leave and there is some event in the frame that John happens to see, even if John does not see any staying event by Mary in the frame.

Our account avoids this problem by ensuring that the truth conditions of (61a) require John neither to see everything in the frame (that would be too strong), nor to just see anything in the frame (that would be too weak); on our account, he has to see an event which precludes the occurrence of any leaving of Mary.

While Schein's (2020) main target is Higginbotham (1983, 2000), our account is similar in spirit to Higginbotham's approach, so it is worth examining whether it is affected by Schein's (2020) arguments. Schein's starting point is the observation that in the scenario below, (62) is false.

(62) [*Context:* An airplane got into a rain storm that iced the plane's wings and was felt by its passengers.]

It not being calm iced the wings. *false*

Schein argues that the negative event description *it not being calm* cannot apply to the storm itself. But clearly the ordinary event description *it being calm* does not apply to the

19 Here, "local" and "local_{past}" are distinct relations, so John need not see his own seeing event.

storm either; so he concludes that event negation violates what he calls Excluded Middle. By this term, Schein means that for any event description and its negation, one or the other holds of any given event. Schein takes this to suggest that event negation, which he regards as "occult", should be avoided. It is indeed the case on our account that for many event predicates P and events e, neither P nor its event negation $Neg(P)$ holds of e. But this by itself is unproblematic. As we have shown in Section 7, our account validates what van Fraassen (1966) and others refer to as Excluded Middle, namely the fact that the disjunction of any sentence with its own (event) negation is true. As for the assumption that the negative event description *it not being calm* does not apply to the storm, it is consistent with accounts like ours (one might think of it, for instance, as describing a shaking event which is caused by the storm).

Another argument of Schein's against event negation is based on the following inference, which Schein takes to be representative of a general principle he calls Perceptual Consistency:

(63) a. The passengers felt it not be calm.
b. ⇒ The passengers did not feel it to be calm.

We account for this inference via the Principle of Negation, whose left-to-right direction (No Gluts) postulates an inconsistency between the occurrence of an event of it not being calm, and the occurrence of an event of it being calm. But Schein points out that a flight in which calm and bumpy stretches alternate can involve events of both these kinds. As he recognizes, this also means that Perceptual Consistency must be qualified; for Schein, it is valid only if premise and conclusion are understood as being about parts of the same framing event, such as a bumpy stretch of the flight. Schein's observation involves time, and as such its treatment is beyond the scope of this paper. That said, one may assume that the event predicate to which *Neg* applies in (63a) is contextually restricted to events at or within a certain time, such as the time supplied by the past tense morpheme (Partee, 1973; Ogihara, 1995). This approach would also account for the relation between unembedded tensed sentences such as *It was calm* and *It wasn't calm*; these sentences are contradictories only if they are understood as being about the same time in the past. An appeal to contextual domain restriction is also used by Schein (2020) himself to account for the validity of the inference in (63) and for the general principle of Perceptual Consistency.

10.6 *Previous work that is formalizable using Neg*

We end this section by highlighting previous work which can be formalized, or whose formalization could be profitably extended, by using the *Neg* function we have introduced.

Structured Discourse Representation Theory (SDRT; Asher & Lascarides, 2003) formalizes the dynamic semantics of discourses by postulating Structured Discourse Representation Structures (SDRS), along with discourse relations that hold between them. Discourse relations are taken to relate the main eventualities introduced by the two SDRSs involved. These are defined as the eventualities introduced by the main verb in a constituent derived from a simple clause or by the main verb of a more complex constituent. For instance, in the following discourse, SDRS postulates an *Explanation* relation between a falling event and a pushing event:

(64) Max fell. John pushed him.

The connection to negative events arises from the need to provide main eventualities for negated sentences. While SDRT represents such sentences using a negation operator on

SDRSs, this operator does not introduce an eventuality. Consequently, in a discourse like *Max fell. John didn't catch him*, the discourse relation has nothing to latch on to. This issue can be addressed by redefining the negation operator in SDRT so that it introduces negative eventualities defined in terms of the *Neg* function.

Fábregas & González Rodríguez (2020) assume, following Klein (1994), that many sentences involving negation are ambiguous between what they call a *sentential negation* reading as in (65a) and an *inhibited eventuality* reading as in (65b):

(65) Juan did not review the article.
  a. It did not happen than Juan reviewed the article.
  b. It happened that Juan did not review the article.

While Fábregas & González Rodríguez (2020) characterize this as a scopal ambiguity, they do not formally specify the denotation of *not* in these cases. We propose to identify inhibiting events as a subset of negative events in our sense. Their inhibited eventuality reading contributes an additional inhibition component tied to the presence of an entity with the teleological capacity to initiate the event. On their account, predicates differ in whether the events they describe can have such initiators, and thus in whether they can give rise to the inhibited eventuality reading. On this reading, the initiator actually initiates the inhibiting eventuality. The denotation of instances of *not* introducing inhibiting events can be expressed by combining *Neg* with a partial function *init* that maps events to their initiators. This way, we can interpret an eventuality of Juan being inhibited from reviewing the article as any event to which the following expression applies:

(66) $\lambda e.\ init(e) = Juan \wedge e \in Neg(\lambda e'.\ ag(e') = Juan \wedge review(e') \wedge th(e') = art)$
(the set of events initiated by Juan that are anti-Juan-reviews-the-article events)

The notion that there are two kinds of negation can be found throughout the generative literature since at least Klima (1964). More recently, Zaradzki (2020) defines a subset of negative events by borrowing *Neg* from precursors of the present article, Bernard & Champollion (2018) and Bernard (2019, ch. 7). Ordinary propositional negation is interpreted as what we have called complement negation. The other kind of negation, *verbal negation*, is argued to appear in perception reports, in the antecedent of *when*, and within double negation. Verbal negation is taken to denote a variation on our *Neg* function with an additional semantic component that expresses a denial of expectation, deliberateness, or some form of intensity. Zaradzki uses this component to capture the kinds of inferences we have left to the pragmatics (see Sections 2 and 9).

Another proposal that is consonant with our framework is found in Mossel (2009), where negative actions exist alongside ordinary actions. A negative action normally consists in intentionally not performing an ordinary action, and can often be described as a refraining. For Mossel, "[a] negative action is not the mere nonoccurrence of an action, but a causing of such a nonoccurrence". Because negative actions preclude events of a certain kind, they can be understood as a subset of the events accessed via our *Neg* function. A negative action might be formalized as an event $e \in Neg(P)$ for some event predicate P such that e involves an individual d who willingly causes the occurrence of e, which in turn causes the nonoccurrence of any $e' \in P$.

Schaffer (2012) argues contra Moore (2009) (which we have discussed in Section 10.4) that events can be described by expressions like "omitting/preventing/failing/etc. to P" or "non P-ing", where P is some event description. To make his point more concrete, Schaffer then suggests that these events satisfy one of the predicates that can be obtained by inserting complement negation into P. For example, he proposes that according to a natural reading of the noun phrase in (67a), the failing events described satisfy the predicate in (67b).

(67) a. Tom's failing to pass the driving test
b. $\lambda e.\ (\neg passing(e)) \wedge ag(e) = Tom \wedge th(e) = driving\_test$
c. (The set of all events by Tom of the driving test that are not passings.)

Schaffer's proposal is similar to the account in Miller (2003), though Schaffer does not specify the scope of the negation operator within the resulting event predicate, leaving it up to speaker intention. Schaffer does seem to be looking for a translation which guarantees that if an event described by (67a) occurs, then Tom did not pass the driving test. Complement negation, however, does not guarantee this. The semantics he argues for can essentially be paraphrased as "Tom was the agent of an event whose theme is the driving test and which was not a passing", which is not strong enough. For example, this semantics is compatible with Tom having administered the driving test rather than taking it. In that case, he did something to the driving test that was not passing it (and he may well still have passed it on a different occasion). While Schaffer criticizes Moore's (2009) assumption that negation always takes wide scope, the problem with Moore's account appears unrelated to scope: the semantics of the cases discussed by Schaffer can be satisfyingly modeled with a negation that takes wide scope over the corresponding positive predicates, as long as negation is interpreted as event negation rather than as complement negation.

11 CONCLUSION

Event semantics offers elegant analyses for a variety of linguistic constructions. However, the traditional interpretation of negation, complement negation, does not mesh satisfyingly with these analyses. Nonstandard approaches according to which negated and nonnegated clauses introduce events either lack generality, are formally incomplete, or do not lend themselves easily to a compositional implementation.

We have proposed a novel account of the interaction of negation and event predicates. On our account, to every set of events P there corresponds a set $Neg(P)$ of events that do not co-occur with any event in P. In addition, if no P event occurs, at least one $Neg(P)$ event does. This is formalized within what we have called the Principle of Negation. Given this principle, the events in $Neg(P)$ can be thought of as anti-P events. The resulting theory is conceptually related to truthmaker semantics; however, we have formalized it using only standard logical tools (namely, an extensional variant of TY_2). We have shown that it interacts well with event semantic accounts of disjunction, collective conjunction, and quantifiers.

We have also shown how *Neg* can be introduced by linguistic negation in the context of compositional semantics. Linguistic negation takes syntactic scope below the subject at the surface level, but *Neg* needs to be able to take semantic scope above it. In this paper, we have resolved this type mismatch by appealing to the VP-internal subject hypothesis.

We have used the resulting theory to account for negated nonfinite perception reports, a construction that poses a challenge for otherwise successful event-based analyses when linguistic negation is interpreted in terms of complement negation. We expect the framework to be simple and versatile enough to be applied to a variety of other linguistic constructions in which event semantics interacts with negation.

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