Event Semantics and Abstract Categorial Grammar

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Abstract. Common versions of event semantics do not naturally explain the obligatory narrow scope of existential quantification over events, or the typically event-oriented modification by adverbials. We argue that these linguistic properties reflect a distinction between overt arguments and purely semantic slots like the event argument. The distinction is naturally captured in *Abstract Categorial Grammar* (ACG) [1, 2, 3, 4], which manipulates pairs of forms and meanings, a.k.a. linguistic *signs*. The sign's *pheno-type* defines syntactic arguments and the sign's semantic type standardly defines semantic arguments. Both these *concrete types* are standardly derived by induction on the structure of one *abstract type* (category) of the sign, by assigning pheno-level and semantic types to basic abstract types. We assume that semantic event arguments are only introduced by the (basic) result type of the verb's abstract type, whose pheno-level type is standardly a string. Consequently semantic event arguments lack a correlate in the verb's pheno-type. Both narrow-scope existential quantification over events and the orientation of event modifiers follow rigorously from this assumption. Based on this architecture, we develop simple accounts of adverbial modification, nominalization and passive constructions in an ACG fragment.

1 Basic Assumptions of Event Semantics

The following sentence illustrates a simple case of adverbial modification.

(1) John danced beautifully in the kitchen.

Such examples raise basic questions concerning the correct semantic type of adverbial expressions like *beautifully* and *in the kitchen*, and the precise way in which their syntax and semantics allows adverbs to reiterate as verbal adjuncts. Davidson's well-known account [5] of adverbial modification takes sentence (1) to represent the following proposition in Predicate Calculus notation.

(2) $\exists \mathsf{e}[\mathbf{dance}(\mathsf{e}, \mathbf{john}) \wedge \mathbf{beautiful}(\mathsf{e}) \wedge \mathbf{in\_the\_kitchen}(\mathsf{e})]$

In this analysis, an intransitive verb like *dance* denotes a binary relation between its overt subject argument and a covert *event argument*. Adverbial expressions are assumed to be one-place predicates over events, which apply to the verbal event argument using conjunctive (intersective) modification. To guarantee that the whole sentence denote a proposition, Davidson introduces an existential quantifier over events, commonly referred to as an *existential closure* operator.

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Parsons' reformulation [6] of Davidson's account decomposes the verb denotation using *thematic roles* like 'agent' or 'patient'. A simple account of thematic roles models them as binary relations between events and other entities. With an 'agent' relation AG, Parsons' analysis of (1) is the following.

(3) $\exists \mathsf{e}[\mathbf{dance}(\mathsf{e}) \wedge \textsc{ag}(\mathsf{e}, \mathbf{john}) \wedge \mathbf{beautiful}(\mathsf{e}) \wedge \mathbf{in\_the\_kitchen}(\mathsf{e})]$

In this 'neo-Davidsonian' analysis, verb denotations are *one-place* predicates over events. This treatment of verb meaning is independent of the number of the verb's overt arguments. Thus, overt arguments of the verb, like the subject argument in (1), are not semantic arguments of the verb's basic meaning. Instead, denotations of syntactic arguments of verbs are indirectly related to the verb meaning using thematic roles like the AG relation in (3).

2 Two Compositionality Problems for Event Semantics

Both the Davidsonian and the neo-Davidsonian versions of event semantics offer an elegant solution to the problem of adverbial modification, as well as to many other important problems in linguistic theory.[1] However, in terms of rigor and explicitness of the compositional process, most works on event semantics are inferior to semantic frameworks that more closely follow traditional Montague Grammar, with its severe matching between syntax and semantics.[2] Below we review two major compositionality problems for event semantics [29].

2.1 The Event Modification Problem

Consider the following example.

(4) The damage surprised John enormously.

The proposition in (5) below is the standard analysis of sentence (4) in neo-Davidsonian event semantics. This analysis is similar to analysis (3) of sentence (1) above.

(5) $\exists \mathsf{e}[\mathbf{surprise}(\mathsf{e}) \wedge \textsc{ag}(\mathsf{e}, \mathbf{the\_damage}) \wedge \textsc{pt}(\mathsf{e}, \mathbf{john}) \wedge \mathbf{enormous}(\mathsf{e})]$
"there is an enormous surprise event, of which the damage is the agent and John is the patient"

Both Davidsonian and neo-Davidsonian theories assume that adverbials like *enormously,* beautifully and *in the kitchen* denote one-place predicates over events. This treatment of adverbials as one-place predicates over entities, intersected with the verbal predicate, is pleasingly parallel to the standard treatment of adnominal adjectives and prepositional phrases. An important semantic advantage of this parallelism is the direct relation that it establishes between meanings of verbal constructions like *to dance beautifully* and

[1] See [7, 8, 9, 10, 11, 12, 6, 13, 14, 15, 16, 17], among others.
[2] See [18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28], among others.

nominal constructions like *beautiful dancing* (section 5).[3] However, once adverbials are assumed to denote ordinary one-place predicates, we need to rule out non-existing interpretations as in (6) and (7) below for sentence (4).

(6) $\exists \mathsf{e}[\mathbf{surprise}(\mathsf{e}) \wedge \text{AG}(\mathsf{e}, \mathbf{the\_damage}) \wedge \text{PT}(\mathsf{e}, \mathbf{john}) \wedge \mathbf{enormous}(\mathbf{the\_damage})]$

"there is a surprise event, of which the damage is the agent and John is the patient, and the damage is enormous"

(7) $\exists \mathsf{e}[\mathbf{surprise}(\mathsf{e}) \wedge \text{AG}(\mathsf{e}, \mathbf{the\_damage}) \wedge \text{PT}(\mathsf{e}, \mathbf{john}) \wedge \mathbf{enormous}(\mathbf{john})]$

"there is a surprise event, of which the damage is the agent and John is the patient, and John is enormous"

An implicit assumption in all versions of event semantics is that adverbials can only modify the event argument of the verb, as in (5). But what compositionality principle prevents adverbials from modifying other arguments of the verb as well, as in (6) and (7)? We refer to this question as the *event modification problem*.[4]

2.2 The Event Quantification Problem

A more familiar problem for event semantics concerns quantificational sentences like the following.

(8) Nobody danced.

Most versions of event semantics assume the analysis in (9) below for sentence (8). However, without further assumptions, we might also expect sentence (8) to have the unacceptable analysis in (10).

[3] Syntactic advantages for this parallelism: (i) English shows no morphological distinction between adverbial uses of PPs (*in the kitchen* in (1)) and predicative PPs (*John is in the kitchen*) or PP nominal modifiers (*the boy in the kitchen*); (ii) in many languages adverbs are also not morphologically distinguished from respective adjectives, similarly to the English words *fast* and *hard*.

[4] This problem concerns "ordinary" adverbial modification, and should be linguistically distinguished from cases where modifiers do, at least apparently, apply to syntactic arguments. First, *secondary predicates* as in *left the room angry* or *ate it cold*, as well as *resultative predicates* such as *painted it red* are generally assumed not to apply to arguments in the main clause, but to introduce an embedded clause, where syntactic arguments are bound to the argument in the main clause [30, 31]. Second, some modifiers are at least semantically oriented to syntactic arguments. Adverbs can be subject-oriented (*Sue greeted Bob reluctantly*, [32]), and PPs can be oriented to different participants, as in *Ada saw Bob at the meeting*, *Ada criticized Bob at the meeting*, or *Ada met Bob at the meeting* [33]. However, see [30] for argumentation that subject-oriented adverbs should be treated as event predicates, despite appearances, and [34], who argues that stative PPs modify events, and that argument orientation is a matter of lexical semantics. For instance, it is a property of meeting events that they have the same location as the participants in those events, but things are different for seeing and criticizing events. We conclude that the event modification problem is quite general, noting that no account known to us can address these lexical variations without first assuming that adverbials are uniformly event-orientated.

(9) $\neg\exists x[\exists \mathsf{e}[\mathbf{dance}(\mathsf{e}) \wedge \text{AG}(\mathsf{e}, x)]]$
"nobody was the agent of any dancing event"

(10) $\exists \mathsf{e}[\neg\exists x[\mathbf{dance}(\mathsf{e}) \wedge \text{AG}(\mathsf{e}, x)]]$
"there was a non-dancing event or a dancing event where nobody was the agent"

Obviously, sentence (8) can only mean (9) in event semantics, with narrow scope existential closure over the event variable, but not (10), where the existential quantifier over events takes wide scope over the quantificational noun phrase *nobody*. More generally, as is evident with any non-upward-monotone quantifiers (*nobody, less than five teachers, exactly one student, between two and five men*), overt quantificational arguments do not show scope ambiguities with the existential quantifier over events, and are required to take it in their scope.[5]

What compositionality principle rules out such wider scopes for the existential closure quantifier over events? We refer to this question as the *event quantification problem*.

2.3 Previous Accounts

The modification problem is not often explicitly addressed. Most works on event semantics assume that adverbials map sets of events to their subsets by intersective modification, but it remains unclear how this process interacts with the compositional integration of the other verbal arguments. In an attempt to solve the event quantification problem, some works on events have proposed syntactic principles that govern the scope of existential closure over events. [36] assumes that the existential binder of the event argument is a syntactic head that corresponds to inflection. Another line follows Diesing's "mapping hypothesis" [37], which has existential closure over free arguments within the VP, including events. In both of these approaches all quantificational NPs must be treated as VP-external. This should rule out analyses such as (10). We would here like to analyze the event quantification problem in a more principled way: why shouldn't the two kinds of quantifiers work the other way around – quantificational noun phrases VP-internally, and existential closure VP-externally? Another, strictly compositional, line in the semantic treatment of events, is found in [38, 12, 15, 13]. These accounts all adopt non-trivial assumptions about the internal structure of events, and introduce events into the logical semantics of quantificational noun phrases. While this approach leads to a compositional semantics with events, it has so far led to remarkable complications in the event ontology and in the syntax-semantics mapping. We believe that

[5] In that, implicit event quantifiers differ from overt event quantifiers like *at least once*:

(i) At least once I met exactly one student.

(ii) I met exactly one student.

(i) means that there are one or more meeting events, each of which involves exactly one student (wide scope reading of *at least once*). This reading is absent for (ii). A similar case to (i), where an adverbial modifier takes scope over a quantifier, is *Alma quickly sliced each bagel* [35], where *quickly* applies to Alma's slicing of all the bagels. In this paper we ignore the possibility that some adverbs show in taking wide scope over quantifiers, since its analysis would take us too far afield. The fragments that we introduce below do not account for cases as in (i) and (ii).

a better approach might be to avoid any complication in the event ontology or lexical meanings that goes beyond what is required by Davidson's/Parsons's basic assumptions (section 1). As we shall see in sections 3 and 4, ACG easily allows us to introduce such a solution.[6]

3 Abstract Categorial Grammar

Both problems that were mentioned above, the event modification problem and the event quantification problem, raise basic questions about the modes of composition available in natural language. We believe that a good strategy for studying these questions is by adopting some minimalist assumptions about the syntax-semantics interface and scoping mechanisms. *Abstract Categorial Grammar* (ACG) is a framework that uses a standard compositional core (the Lambek-Van Benthem Calculus) for deriving all scoping possibilities for operators.[7] This distinguishes ACG from other frameworks, including other versions of categorial grammar, which introduce special principles, rules or logical constructors in order to account for "non-surface" scoping of linguistic expressions. Because of its simple treatment of scope, we consider ACG optimal for developing hypotheses about compositionality in event semantics, where scoping and modification possibilities must be severely restricted.

In ACG, as in other versions of categorial grammar, the syntax-semantics matching is described using a homomorphism between the two domains. The basic items that ACG manipulates are compound linguistic resources, or *signs*. A sign describes information of different grammatical levels (phonetic, syntactic, semantic, etc.) about a linguistic expression EXP. Specifically, each sign must specify *pheno-level* information about EXP's articulation, and *semantic* information pertaining to EXP's meaning. Here we adopt a minimalist definition of linguistic signs where only pheno-level and semantic information is described at the sign level. This minimalist grammar architecture makes it easier

[6] Recently, [39] and [40] have provided a radically new approach to verb semantics, different from both Montagovian and Davidsonian semantics, which makes use of partial assignment functions. As will become clear, our approach solves the problem without such heavy amendments to standard semantic assumptions. We defer a comparison with these proposals to another occasion. Another recent idea, proposed in [41], is to introduce the existential quantifier over events within a neo-Davidsonian denotation of the verb, and to allow predicates over events to be direct arguments of the verb. E.g., a verb like *dance* denotes in this approach a set of sets of events: $\lambda P_{et}.\exists \mathsf{e}.\mathbf{dance}(\mathsf{e}) \wedge P(\mathsf{e})$. Adjuncts and arguments alike are treated as denoting mappings from sets of sets of events to sets of sets of events. E.g., the subject *John* denotes the mapping $\lambda Q_{(et)t}.\lambda P_{et}.Q(\lambda \mathsf{e}.P(\mathsf{e}) \wedge \textsc{ag}(\mathsf{e}) = \mathbf{john})$, and the adverb *beautifully* should denote the mapping $\lambda Q_{(et)t}.\lambda P_{et}.Q(\lambda \mathsf{e}.P(\mathsf{e}) \wedge \mathbf{beautiful}_{et}(\mathsf{e}))$. Such verbal "modifiers" apply to the existential denotation of the verb, and a "closure" operation supplies the resulting verb phrase denotation with a trivial predicate $\lambda \mathsf{e}.\top$. We take it that this technique is more complicated than the one we propose here using ACG, but further comparison of the two approaches must also be deferred to further work.

[7] Early precursors to ACG are [1], [42] and [2]. The framework we refer to as *ACG* basically follows the works of [3] and [4], using some ideas from [43]. Some differences between these works are ignored here. For more work in the ACG framework, see [44, 45] and references therein.

to introduce our core hypothesis on event semantics with as few additional assumptions as possible.

For the inductive specification of functional types and their domains, we use the following standard definition.

Definition 1. *Let* B *be a finite set of basic types, where for each basic type* $\tau \in \mathsf{B}$*, the corresponding domain is a set* D_τ*. The set of* **types** *over* B *is the smallest set* $\mathcal{T}^{\mathsf{B}}$ *containing* B *that satisfies: if* τ *and* σ *are types in* $\mathcal{T}^{\mathsf{B}}$ *then* $(\tau \to \sigma)$ *(in short: '*$\tau\sigma$*') is also a type in* $\mathcal{T}^{\mathsf{B}}$*.*

For each type $\tau\sigma \in \mathcal{T}^{\mathsf{B}}$*, the corresponding* **domain** *is* $D_{\tau\sigma} = D_\sigma^{D_\tau}$*.*

The domains for pheno-level objects are defined inductively as strings and functions over strings. The basic domain of strings, defined below, is given the basic type '*f*'.[8]

Definition 2. *The domain of strings* D_f *is any non-empty set closed under an associative concatenation operator* $\bullet$*.*

The set of *pheno-level types* (*f-types*) is the set $\mathcal{T}^{\{f\}}$, or in short $\mathcal{T}^f$. The set of extensional *semantic types* (*s-types*) is standardly $\mathcal{T}^{\{e,t\}}$, or in short $\mathcal{T}^{e,t}$. Also standardly, we assume that D_e, the domain of semantic entities, is an arbitrary non-empty set, and that D_t, the domain of truth-values, is the set $\{\bot, \top\}$ ordered by implication.

Let Σ be a finite set, called a *sign-vocabulary*. Each sign in Σ has an f-type and an s-type. In order to establish a relation between the f-type and the s-type of a sign, we assume that both types are derived from one *abstract type*. The abstract types of signs correspond to traditional categories in non-directed categorial grammar. From an abstract type we derive an f-type and an s-type using the following definition.

Definition 3. *Let* A *be a finite set of* <u>*basic*</u> *abstract types. Let* $F_0 : A \to \mathcal{T}^f$ *and* $S_0 : A \to \mathcal{T}^{e,t}$ *map each basic abstract type to an f-type and an s-type, respectively. For each abstract type* $\tau \in \mathcal{T}^A$*, the* **concrete f-type and s-type** *of* τ *are defined inductively, by the following minimal extensions* F *and* S *of* F_0 *and* S_0 *to the domain* $\mathcal{T}^A$ *of all abstract types.*

(i) $F : \mathcal{T}^A \to \mathcal{T}^f$ *is the minimal extension of* F_0 *that satisfies for each abstract type* $(\tau \to \sigma) \in \mathcal{T}^A$*:* $F(\tau \to \sigma) = (F(\tau) \to F(\sigma))$*.*
(ii) $S : \mathcal{T}^A \to \mathcal{T}^{e,t}$ *is the minimal extension of* S_0 *that satisfies for each abstract type* $(\tau \to \sigma) \in \mathcal{T}^A$*:* $S(\tau \to \sigma) = (S(\tau) \to S(\sigma))$*.*

Let $\Upsilon \in \Sigma$ be a sign of abstract type $\tau \in \mathcal{T}^A$ and concrete types $\langle F(\tau), S(\tau)\rangle$. In a given *sign-model* M, the *interpretation* $[\![\Upsilon]\!]^M$ of Υ in M is a pair $\langle x, y\rangle$ s.t. $x \in D_{F(\tau)}$ is Υ's *f*-interpretation and $y \in D_{S(\tau)}$ is Υ's *s*-interpretation. Thus, signs are interpreted both in their pheno-level domain and in their semantic domain.

[8] For our purposes here, definition 2 assumes the set of strings to be a semigroup, without necessarily requiring it to be a free monoid (adding an empty string and a finiteness requirement on strings). Adding these further assumptions may of course be required in a fuller syntactic framework.

For a sign-vocabulary Σ, let A be a set of basic abstract types with the corresponding F_0 and S_0 functions. An *ACG lexicon* over Σ maps each sign $\Upsilon \in \Sigma$ to Υ's abstract type in $\mathcal{T}^A$ and to restrictions on Υ's possible interpretations. Consider for example the ACG-lexicon in parts A and B of Table 1, where $A = \{\mathsf{np}, \mathsf{s}\}$ and F_0 and S_0 satisfy:

$$F_0(\mathsf{np}) = f \quad S_0(\mathsf{np}) = e$$
$$F_0(\mathsf{s}) = f \quad S_0(\mathsf{s}) = t$$

Using two basic abstract types and their concrete types, we thus distinguish between two kinds of *string signs* – signs of the concrete f-type f. String signs of abstract type np ("noun phrase") have the concrete s-type e; string signs of abstract type s ("sentence") have the concrete s-type t. The sign D, for the verb *dance*, of abstract type $\mathsf{np} \to \mathsf{s}$, is standardly assumed to have as its s-interpretation an arbitrary non-logical constant of type et. The f-interpretation of D, however, is fixed as the ff function concatenating its string argument to the left of the string *danced* (the past tense is used for convenience). Similarly the f-interpretation of the sign P (for *praise*) has two arguments, for the subject and the object strings, positioned before and after the string *praised*, respectively. In signs for quantificational nominal phrases, with the standard s-type $(et)t$, the concretization of abstract types requires using as their f-interpretation a lifted string of type $(ff)f$. For instance, the quantifier sign $\mathsf{Q}_\forall$ (for *everyone*) has as its f-interpretation a function that takes an ff function as its argument, and applies it to the string $everyone$.

The calculus used for generating compound signs from lexical signs is the non-directional *Lambek-Van Benthem Calculus* [46], which is a standard implicational logic with function application as the semantics of implication-elimination, and function abstraction as the semantics of implication-introduction. In natural deduction format we get the following definition.

Table 1. An event-free ACG lexicon

	sign	**abbr**	**abs-type**	**con-types**	**interpretation**
A.	JOHN	J	np	$\langle f\, , e\rangle$	$\langle john_f\, , \mathbf{john}_e\rangle$
	SOMEONE	$\mathsf{Q}_\exists$	$(\mathsf{np} \to \mathsf{s}) \to \mathsf{s}$	$\langle (ff)f\, , (et)t\rangle$	$\langle \lambda A_{ff}.A(someone_f)\, , \lambda A_{et}.\exists x_e.A(x)\rangle$
	EVERYONE	$\mathsf{Q}_\forall$	$(\mathsf{np} \to \mathsf{s}) \to \mathsf{s}$	$\langle (ff)f\, , (et)t\rangle$	$\langle \lambda B_{ff}.B(everyone_f)\, , \lambda B_{et}.\forall y_e.B(y)\rangle$
	NOBODY	$\mathsf{Q}_\neg$	$(\mathsf{np} \to \mathsf{s}) \to \mathsf{s}$	$\langle (ff)f\, , (et)t\rangle$	$\langle \lambda C_{ff}.C(nobody_f)\, , \lambda C_{et}.\neg\exists z_e.C(z)\rangle$
B.	DANCE	D	$\mathsf{np} \to \mathsf{s}$	$\langle ff\, , et\rangle$	$\langle \lambda y_f.\, y \bullet danced_f\, , \mathbf{dance}_{et}\rangle$
	PRAISE	P	$\mathsf{np} \to (\mathsf{np} \to \mathsf{s})$	$\langle f(ff)\, , e(et)\rangle$	$\langle \lambda x_f.\lambda y_f.\, y \bullet praised_f \bullet x\, , \mathbf{praise}_{e(et)}\rangle$
C.	STUDENT	S	n	$\langle f\, , et\rangle$	$\langle student_f\, , \mathbf{student}_{et}\rangle$
	BEAUTIFUL	B	$\mathsf{n} \to \mathsf{n}$	$\langle ff\, , (et)(et)\rangle$	$\langle \lambda x_f.beautiful_f \bullet x\, , \lambda A_{et}.\lambda x_e.A(x) \wedge \mathbf{beautiful}_{et}(x)\rangle$
	SOME		$\mathsf{n} \to ((\mathsf{np} \to \mathsf{s}) \to \mathsf{s})$	$\langle f((ff)f)\, , (et)((et)t)\rangle$	$\langle \lambda u_f.\lambda V_{ff}.V(some_f \bullet u)\, , \lambda U_{et}.\lambda V_{et}.\exists y_e.U(y) \wedge V(y)\rangle$
	EXIST		$\mathsf{np} \to \mathsf{s}$	$\langle ff\, , et\rangle$	$\langle \lambda y_f.y \bullet existed_f\, , \lambda y_e.\top\rangle$
	RAFT	R	np	$\langle f\, , e\rangle$	$\langle the_f \bullet raft_f\, , \mathbf{r}_e\rangle$

Definition 4. Lambek-Van Benthem Calculus:

Elimination

$$\frac{\mathtt{A} : \tau \to \sigma \quad \mathtt{B} : \tau}{\mathtt{A}(\mathtt{B}) : \sigma}$$

Introduction

$$\cfrac{\cfrac{\begin{array}{c}\dots \quad [A : \tau]^i \\ \vdots \end{array}}{\mathtt{B} : \sigma}}{\lambda A.\mathtt{B} : \tau \to \sigma}\ \textit{discharge hypothesis } i$$

Permutation

$$\frac{\mathtt{A} : \tau \quad \mathtt{B} : \sigma}{\mathtt{B} : \sigma \quad \mathtt{A} : \tau}$$

In this definition, we denote for each two sign interpretations $\mathtt{A} : \tau = \langle x_1, y_1 \rangle$ and $\mathtt{B} : \sigma = \langle x_2, y_2 \rangle$:

(11) $\mathtt{A}(\mathtt{B}) = \langle x_1(x_2), y_1(y_2) \rangle$ is a sign of type σ', if $\tau = \sigma \to \sigma'$.
$\lambda A.\mathtt{B} = \langle \lambda x_1.x_2, \lambda y_1.y_2 \rangle$ is a sign of type $\tau \to \sigma$.

Thus, application and abstraction at the sign level are interpreted pointwise for each of the coordinates in the sign's interpretation.

Consider a maximally simple sentence like *John danced*. Given the signs $\mathtt{J} : \mathsf{np}$ (for *John*) and $\mathtt{D} : \mathsf{np} \to \mathsf{s}$ (for *danced*), the Lambek-Van Benthem Calculus derives the following sign:

(12) $\mathtt{D}(\mathtt{J}) : \mathsf{s}$
$= \langle (\lambda y_f.\ y \bullet \mathit{danced}_f)(\mathit{john}_f)\ ,\ \mathbf{dance}_{et}(\mathbf{john}_e) \rangle$
$= \langle \mathit{john} \bullet \mathit{danced}\ ,\ \mathbf{dance}(\mathbf{john}) \rangle$

In the derived sign, the string $\mathit{john} \bullet \mathit{danced}$ is associated with the truth-value $\mathbf{dance}(\mathbf{john})$.

Quantifiers in object positions are treated using the Introduction rule of the Lambek-Van Benthem Calculus. For instance, one of the derivations we get using the signs $\mathtt{Q}_\exists$ (for *someone*), $\mathtt{P}$ (for *praised*) and $\mathtt{Q}_\forall$ (for *everyone*) is:

(13)

$$\cfrac{\mathtt{Q}_\exists : (\mathsf{np}\to\mathsf{s})\to\mathsf{s} \qquad \cfrac{\cfrac{\cfrac{\cfrac{\cfrac{\cfrac{\mathtt{P} : \mathsf{np}\to(\mathsf{np}\to\mathsf{s}) \quad [U : \mathsf{np}]^1}{\mathtt{P}(U) : \mathsf{np}\to\mathsf{s}} \quad [V : \mathsf{np}]^2}{\mathtt{P}(U)(V) : \mathsf{s}}}{\lambda U.\mathtt{P}(U)(V) : \mathsf{np}\to\mathsf{s}}\ \textit{discharge 1} \quad \mathtt{Q}_\forall : (\mathsf{np}\to\mathsf{s})\to\mathsf{s}}{\mathtt{Q}_\forall(\lambda U.\mathtt{P}(U)(V)) : \mathsf{s}}}{\lambda V.\mathtt{Q}_\forall(\lambda U.\mathtt{P}(U)(V)) : \mathsf{np}\to\mathsf{s}}\ \textit{discharge 2}}{\mathtt{Q}_\exists(\lambda V.\mathtt{Q}_\forall(\lambda U.\mathtt{P}(U)(V))) : \mathsf{s}}$$

And by the lexical definitions of the signs $\mathtt{Q}_\exists$, $\mathtt{Q}_\forall$ and $\mathtt{P}$ we get:[9]

(14) $\mathtt{Q}_\exists(\lambda V.\mathtt{Q}_\forall(\lambda U.\mathtt{P}(U)(V))) : \mathsf{s}$

$= \langle\ (\lambda A_{ff}.A(\mathit{someone}_f))(\lambda v_f.(\lambda B_{ff}.B(\mathit{everyone}_f))(\lambda u_f.(\lambda x_f.\lambda y_f.y \bullet \mathit{praised}_f \bullet x)(u)(v)))\ ,$
$(\lambda A_{et}.\exists x_e.A(x))(\lambda v_e.(\lambda B_{et}.\forall y_e.B(y))(\lambda u_e.\mathbf{praise}_{e(et)}(u)(v)))\ \rangle$

$= \langle \mathit{someone} \bullet \mathit{praised} \bullet \mathit{everyone}\ ,\ \exists x.\forall y.\mathbf{praise}(y)(x) \rangle$

[9] Here and henceforth we use the equality '=' sign informally for representing both β-equivalences and logical equivalences resulting from our assumed semantics.

Using the Lambek-Van Benthem Calculus, the same three signs for *someone*, *praised* and *everyone* can also combine to derive the same string as in (14), but with the object wide scope reading:

(15) $\mathsf{Q}_\forall(\lambda U.\mathsf{Q}_\exists(\mathsf{P}(U))) : \mathsf{s}$

$$= \langle\ (\lambda B_{ff}.B(everyone_f))(\lambda u_f.(\lambda A_{ff}.A(someone_f))(\lambda x_f.\lambda y_f.\ y \bullet praised_f \bullet x)(u))\ ,$$
$$(\lambda B_{et}.\forall y_e.B(y))(\lambda u_e.(\lambda A_{et}.\exists x_e.A(x))(\mathbf{praise}_{e(et)}(u)))\ \rangle$$

$$= \langle someone \bullet praised \bullet everyone\ ,\ \forall y.\exists x.\mathbf{praise}(y)(x)\rangle$$

Symmetrically, using the three signs for *someone*, *praised* and *everyone*, we can also derive two string signs of abstract category s (sentence) also for the string $everyone \bullet praised \bullet someone$, with the object narrow scope and object wide scope readings. The matching between the pheno-level coordinate and the semantic coordinate of signs makes sure that a noun phrase in a subject (object) position is interpreted in the same semantic argument, independently of its scope with respect to noun phrases in other positions. Thus, in total the three signs for *someone*, *praised* and *everyone* derive four sentential signs – two strings, each string with two readings – as intuitively required [4].[10]

Parts A and B of Table 1 only involve two basic abstract types, for truth-values (s) and entities (np). Part C of Table 1 illustrates the standard categorial treatment of nouns, nominal modifiers and determiners. This treatment adds a basic abstract type n for common nouns, which is assigned the following concrete types.

$F_0(\mathsf{n}) = f \quad S_0(\mathsf{n}) = et$

This allows a standard intersective treatment of nominal modification, as in the following analysis of the nominal *beautiful student*:

(16) $\mathsf{B}(\mathsf{S}) : \mathsf{n} \to \mathsf{n}$

$$= \langle(\lambda x_f.beautiful_f \bullet x)(student_f)\ ,\ (\lambda A_{et}.\lambda x_e.A(x) \wedge \mathbf{beautiful}_{et}(x))(\mathbf{student}_{et})\rangle$$
$$= \langle beautiful \bullet student\ ,\ \lambda x_e.\mathbf{student}(x) \wedge \mathbf{beautiful}(x)\rangle$$

Because nominal signs are treated as having a semantic e-type argument that has no parallel in their f-type, their modification as in (16) is straightforward. Our Davidsonian treatment of verbs in ACG uses a similar account for verbal signs.

4 Davidsonian Verb Signs in ACG

The Davidsonian approach amounts to assuming that verbs, similarly to nouns, involve a basic category – or in ACG, a basic abstract type – that denotes a *set of events*. We denote this abstract type 'vp' ("verb phrase"), and assign it the same concrete types as the abstract type n of nominals.

[10] This is in contrast to the purely semantic use of the Lambek-Van Benthem calculus, where the same four different meanings are incorrectly derived for each of the two grammatical orderings *someone praised everyone* and *everyone praised someone*. For instance, *someone praised everyone* receives two unacceptable analyses where *everyone* takes the subject position, either narrow scope or wide scope [46, 24, 4].

$F_0(\mathsf{vp}) = f \quad S_0(\mathsf{vp}) = et$

In our proposal events are treated as ordinary e-type entities, with no dedicated type or sort. This allows treating event-denoting nominals (e.g. *destruction*) and gerunds (e.g. *dancing*) as ordinary et-type nouns, and establishing the proper semantic relation between their modified forms (e.g. *beautiful dancing*) and modified verbs like *dance beautifully* (see section 5). We replace the verbal part B of the lexicon in Table 1 by the verbal lexicon B' in Table 2. The Davidsonian signs for verbs in part B' of Table 2 are D^D and P^D. As compared to the standard verbal signs D and P in Table 1, the signs D^D and P^D contain an additional event argument in their s-interpretation. For convenience, we denote entity variables that are used in this event argument by 'e', to distinguish them from entity variables in other, 'standard', argument positions. The resulting binary relation $\mathbf{dance}^D$ and trinary relation $\mathbf{praise}^D$ are the s-interpretations of these verbal signs, respectively. The f-interpretation of verbal signs remains unchanged, since the additional event argument has no f-level correlate.

With the abstract type vp, treating adverbial modification is straightforward, and analogous to the standard treatment of intersective adjectival modification in (16). The adverbial sign BEAUTIFULLY in Table 2 is semantically identical to the adjectival sign BEAUTIFUL in Table 1, but syntactically it is treated as an vp modifier, of abstract type $\mathsf{vp} \rightarrow \mathsf{vp}$. This captures the Davidsonian intuition that there is no semantic difference between adnominal and adverbial modifiers. The differences between these modifiers are in their syntax and morphology, but not in their meaning. Since verbal signs like DANCE^D and PRAISE^D have np arguments, composing them with an adverbial requires using the implication Introduction rule, as in the following derivation.

(17)

$$\dfrac{\dfrac{\mathsf{B}_{adv} : \mathsf{vp} \rightarrow \mathsf{vp} \qquad \dfrac{\mathsf{D}^D : \mathsf{np} \rightarrow \mathsf{vp} \quad [U : \mathsf{np}]^1}{\mathsf{D}^D(U) : \mathsf{vp}}}{\mathsf{B}_{adv}(\mathsf{D}^D(U)) : \mathsf{vp}}}{\lambda U.\mathsf{B}_{adv}(\mathsf{D}^D(U)) : \mathsf{np} \rightarrow \mathsf{vp}} \; \textit{discharge 1}$$

We consider the use of hypothetical reasoning in (17) as necessary for capturing Davidson's assumption that adverbials modify the event argument. Without hypothetical reasoning (or another abstraction technique over "free variables"), it is hard to see how an adverbial one-place predicate over events can modify the event argument in a

Table 2. Davidsonian parts of ACG lexicon

	sign	abbr	abs-type	con-types	interpretation
B'.	DANCE^D	D^D	$\mathsf{np} \rightarrow \mathsf{vp}$	$\langle ff\,,\, e(et)\rangle$	$\langle \lambda y_f.\, y \bullet danced_f\,,\, \mathbf{dance}^D_{e(et)}\rangle$
	PRAISE^D	P^D	$\mathsf{np} \rightarrow (\mathsf{np} \rightarrow \mathsf{vp})$	$\langle f(ff)\,,\, e(e(et))\rangle$	$\langle \lambda x_f.\lambda y_f.\, y \bullet praised_f \bullet x\,,\, \mathbf{praise}^D_{e(e(et))}\rangle$
	$\mathsf{DANCING}^D$		n	$\langle f\,,\, et\rangle$	$\langle dancing_f\,,\, \lambda \mathsf{e}_e.\exists z_e.\mathbf{dance}^D_{e(et)}(z)(\mathsf{e})\rangle$
D.	BEAUTIFULLY	B_{adv}	$\mathsf{vp} \rightarrow \mathsf{vp}$	$\langle ff\,,\, (et)(et)\rangle$	$\langle \lambda x_f.\, x \bullet beautifully_f\,,\, \lambda A_{et}.\lambda x_e.A(x) \wedge \mathbf{beautiful}_{et}(x)\rangle$
	∃-CLOSURE	EC	$\mathsf{vp} \rightarrow \mathsf{s}$	$\langle ff\,,\, (et)t\rangle$	$\langle \lambda z_f.z\,,\, \lambda E_{et}.\exists \mathsf{e}_e.E(\mathsf{e})\rangle$

Davidsonian verb denotation, which constitutes an n-ary relation with $n \geq 2$ (a relation between the event argument and the other entity arguments). In our framework, event arguments of verbs are semantic e-type arguments with no string-level correlate, similarly to the "purely semantic" entity arguments of nominals. As a result, adverbial modifiers must have the f-type ff, and therefore they cannot modify syntactic np arguments of the verb: the f-type ff of adverbials cannot combine directly with the f-type ff of intransitive verbs. This proposed general solution to the event modification problem is reflected in the simple fact below about the signs we use for names, intransitive verbs and adverbs.

Fact 1 . *From the signs* J, D^D *and* B_{adv}*, the only sign derivable (wit. (17)) in the Lambek-Van Benthem Calculus is the sign* $\mathrm{B}_{adv}(\mathrm{D}^D(\mathrm{J}))$.

In the Davidsonian treatment, a verb saturated by its syntactic arguments does not denote a truth-value, but a set of events. Let us denote the type for this set ϵ (in our proposal $\epsilon = et$). To complete our Davidsonian fragment, we have to make sure that propositional operators like quantifiers can compose with verbal meanings of type ϵ. There are two ways in which this has been achieved in the literature: (i) by letting quantifiers apply in the domain for sets of events instead of the propositional domain; and/or (ii) by adding a Davidsonian operator of *existential closure* over events. Option (i) is adopted by some previous proposals [38, 12, 15, 13], which sometimes see reasons to adopt option (ii) as well. Option (i) involves remarkable complications in the meaning of lexical determiners like *every* and *some*, or quantifiers like *everyone* or *someone*, which must be assigned the semantic type $(e\epsilon)\epsilon$, where ϵ is the type for sets of events. This is a significant departure from the traditional assumption that quantifiers are mappings to the propositional domain. In many previous proposals, option (i) furthermore leads to more complications of the event ontology by assuming a complex algebraic structure to the domain of events.

In our proposal, we adopt the Davidsonian approach in option (ii), and add a sign EC for an *existential closure* operator, of the abstract type vp → s as in Table 2.[11] At the f-level, this sign has covert phonology, i.e. it denotes the identity function on strings. At the s-level, it denotes an existential quantifier. This is sufficient for treating quantifiers in a small event-based ACG fragment, accounting for the event quantification problem.

As a simple example, let us first use EC for deriving a sign of abstract type s for the simple sentence *John danced beautifully*:

(18) $\mathrm{EC}((\lambda U.\mathrm{B}_{adv}(\mathrm{D}^D(U)))(\mathrm{J})) : \mathrm{s}$

$= \langle\ (\lambda z_f.z)((\lambda u_f.(\lambda x_f.\ x \bullet \mathit{beautifully}_f)((\lambda y_f.\ y \bullet \mathit{danced}_f)(u)))(\mathit{john}))\ ,$
$(\lambda E_{et}.\exists \mathrm{e}_e.E(\mathrm{e}))((\lambda u_e.(\lambda A_{et}.\lambda x_e.A(x) \wedge \mathbf{beautiful}_{et}(x))(\mathbf{dance}^D_{e(et)}(u)))(\mathbf{john}_e))\ \rangle$

$= \langle\ \mathit{john} \bullet \mathit{danced} \bullet \mathit{beautifully}\ ,\ \exists \mathrm{e}.\mathbf{dance}^D(\mathbf{john})(\mathrm{e}) \wedge \mathbf{beautiful}(\mathrm{e})\ \rangle$

As Fact 1 entails, this is the only sign derived for this string using our Davidsonian lexicon. The event quantification problem is solved similarly to this solution of the event modification problem. Since verbal signs like DANCE^D and PRAISE^D have np arguments,

[11] In a more comprehensive fragment, we should like to describe existential closure of events without phonologically empty signs like EC. For two different ways of achieving that within dynamic semantics, see [47, 48].

composing them with the existential closure sign $\mathtt{EC}$ and quantificational NPs of abstract type $(\mathsf{np} \rightarrow \mathsf{s}) \rightarrow \mathsf{s}$ requires using hypothetical reasoning, as in the following derivation for the sentence *nobody danced*.

(19)

$$\dfrac{\mathtt{Q}_{\neg} : (\mathsf{np} \rightarrow \mathsf{s}) \rightarrow \mathsf{s} \qquad \dfrac{\dfrac{\mathtt{EC} : \mathsf{vp} \rightarrow \mathsf{s} \qquad \dfrac{\mathtt{D}^{D} : \mathsf{np} \rightarrow \mathsf{vp} \qquad [U : \mathsf{np}]^{1}}{\mathtt{D}^{D}(U) : \mathsf{vp}}}{\mathtt{EC}(\mathtt{D}^{D}(U)) : \mathsf{s}}}{\lambda U.\mathtt{EC}(\mathtt{D}^{D}(U)) : \mathsf{np} \rightarrow \mathsf{s}}\ \textit{discharge 1}}{\mathtt{Q}_{\neg}(\lambda U.\mathtt{EC}(\mathtt{D}^{D}(U))) : \mathsf{s}}$$

$$= \langle \textit{nobody} \bullet \textit{danced}\ ,\ \neg\exists x_e.\exists \mathsf{e}_e.\mathbf{dance}^{D}(x)(\mathsf{e}) \rangle$$

In our framework, the existential closure sign $\mathtt{EC}$, like adverbial modifiers (e.g. $\mathtt{B}_{adv}$), has the f-type ff. For this reason the sign $\mathtt{EC}$ must apply to the vp result of a verb sign v before any quantificational NP sign can saturate any np argument of v. This allows the existential closure quantifier to be interpreted in the scope of overt quantifiers, but not the other way around. This gives the impression that $\mathtt{EC}$ only ranges over "event" entities.[12] This general solution that we propose for the event quantification problem is reflected in the simple facts below about the signs we use for quantificational NPs, (in)transitive verbs and the existential closure operator.

Fact 2 . *From the signs* $\mathtt{Q}_{\neg}$*,* $\mathtt{D}^{D}$ *and* $\mathtt{EC}$*, the only sign derivable (wit. (19)) in the Lambek-Van Benthem Calculus is the sign* $\mathtt{Q}_{\neg}(\lambda U.\mathtt{EC}(\mathtt{D}^{D}(U)))$.

A similar fact holds for transitive verbs like *praise*:

Fact 3 . *From the signs* $\mathtt{Q}_{\exists}$*,* $\mathtt{Q}_{\forall}$*,* $\mathtt{P}^{D}$ *and* $\mathtt{EC}$*, the only four signs derivable in the Lambek-Van Benthem Calculus are the following:*

$\mathtt{Q}_{\exists}(\lambda U.\mathtt{Q}_{\forall}(\lambda V.\mathtt{EC}(\mathtt{P}^{D}(V)(U))))$; $\quad \mathtt{Q}_{\forall}(\lambda V.\mathtt{Q}_{\exists}(\lambda U.\mathtt{EC}(\mathtt{P}^{D}(V)(U))))$;
$\mathtt{Q}_{\forall}(\lambda U.\mathtt{Q}_{\exists}(\lambda V.\mathtt{EC}(\mathtt{P}^{D}(V)(U))))$; $\quad \mathtt{Q}_{\exists}(\lambda V.\mathtt{Q}_{\forall}(\lambda U.\mathtt{EC}(\mathtt{P}^{D}(V)(U))))$.

Thus – while the scope interaction possibilities between signs like $\mathtt{Q}_{\forall}$, $\mathtt{Q}_{\exists}$ or $\mathtt{Q}_{\neg}$ for quantificational NPs are retained [4], the existential closure sign $\mathtt{EC}$ is scopally inert, and must take narrow scope with respect to these quantifiers.

Summary: *In an event-free lexicon (Table 1) all verbs have* s*-ending abstract types. This ending for verb types was systematically replaced by* vp *in a Davidsonian lexicon (Table 2). All verbs retain their standard f-interpretation, while s-interpretations of verbs are added an event argument. The event modification problem and the event quantification problems are immediately solved by assuming adverbial modifiers and an existential closure operator that apply to signs of abstract type* vp.

We consider this the simplest solution known to the two problems, and hence, a sound basis for integrating events into Montagovian semantics of categorial grammar.

[12] We hypothesize that the same operator can be used for deriving for existential interpretations of bare nominals (e.g. English bare plurals), but this question requires further research.

5 Neo-Davidsonian Verb Signs in ACG

The Davidsonian approach allows a simple treatment of *nominalization* phenomena, where nouns have a meaning closely related to verbal meaning. Consider for instance the entailment from sentence (20) to sentence (20a), which contains the gerundial noun *dancing*. Alternatively, we also consider the slightly artificial equivalent of (20a) in (20b).

(20) John danced beautifully.
  a. ⇒ There was a beautiful dancing.
  b. ⇒ Some beautiful dancing existed.

The Davidsonian lexicon of Table 2 contains a nominal sign $\mathsf{DANCING}^{D}$ for the noun *dancing*, which allows treating (20b) as follows.

(21) $(\mathsf{SOME}(\mathsf{B}(\mathsf{DANCING}^{D})))(\mathsf{EXIST}) : \mathsf{s}$

$$= \langle\ (\lambda u_f.\lambda V_{ff}.V(some_f \bullet u))((\lambda x_f.beautiful_f \bullet x)(dancing_f))(\lambda y_f.y \bullet existed_f)\ ,$$
$$(\lambda U_{et}.\lambda V_{et}.\exists r_e.U(r) \wedge V(r))((\lambda A_{et}.\lambda x_e.A(x) \wedge \mathbf{beautiful}_{et}(x))$$
$$(\lambda \mathsf{e}_e.\exists z_e.\mathbf{dance}^{D}_{e(et)}(z)(\mathsf{e})))(\lambda y_e.\top)\ \rangle$$
$$= \langle\ some \bullet beautiful \bullet dancing \bullet existed\ ,\ \exists r.(\exists z.\mathbf{dance}^{D}(z)(r)) \wedge \mathbf{beautiful}(r)\ \rangle$$

The s-interpretation of the sign derived in (21) for sentence (20b) is entailed of course by the s-interpretation of the sign derived in (18) for sentence (20). Note that for the stative predicate *exist*, we assume the standard abstract type $\mathsf{np} \rightarrow \mathsf{s}$. This encodes our assumption that existence claims do not involve quantification over events.[13]

In the Davidsonian approach, the relationship between nominals like *dancing* and verbs like *dance* is described by "existentially closing" the verbal subject argument in the denotation $\lambda \mathsf{e}.\exists z.\mathbf{dance}^{D}(z)(\mathsf{e})$ of the noun. Neo-Davidsonian theories take an opposite approach, and "add arguments" to verbal entries, based on partial functions over the domain of events. For example, we assume two partial functions AG and PT of type $e(et)$, which map event entities to their agents and patients respectively. Formally:

Definition 5. *In every model, for each entity x in D_e: each of the predicates* $\mathrm{AG}(x)$ *and* $\mathrm{PT}(x)$ *characterizes either a singleton subset of D_e or the empty set.*

When the set characterized by $\mathrm{AG}(x)$ is a singleton $\{y\}$, we say that x is an *event with agent y*. Similarly, when the set characterized by $\mathrm{PT}(x)$ is a singleton $\{z\}$, we call x an *event with patient z*.[14] In the neo-Davidsonian approach, a nominal like *dancing* denotes an arbitrary set of entities ("events"). The denotation of an intransitive verb like *dance* is derived from this set using the function AG, as illustrated in the lexicon of Table 3.

[13] Whether this is true for stative verbs in general (as proposed in [49]) is a thorny issue that we cannot address here. While [5] suggests that there is a class of verbs that lack an event argument, [6] assumes the event argument for all verbs . Both lines are well represented in the literature.

[14] We do not allow more than one agent or more than one patient per event. Some works have suggested allowing multiple agents/patients as a way of interpreting plural NPs, which are not treated here.

Table 3. Neo-Davidsonian parts of ACG lexicon

	sign	abbr	abs-type	con-types	interpretation
B”.	$\mathtt{DANCE}^{ND}$	$\mathtt{D}^{ND}$	$\mathtt{np} \to \mathtt{vp}$	$\langle\, ff\,,$ $e(et)\,\rangle$	$\langle\, \lambda y_f.\ y \bullet danced_f\,,$ $\lambda y_e.\lambda \mathsf{e}_e.\mathbf{dance}^{ND}_{et}(\mathsf{e}) \wedge \textsc{ag}(\mathsf{e}, y)\rangle$
	$\mathtt{PRAISE}^{ND}$	$\mathtt{P}^{ND}$	$\mathtt{np} \to (\mathtt{np} \to \mathtt{vp})$	$\langle\, f(ff)\,,$ $e(e(et))\,\rangle$	$\langle\, \lambda x_f.\lambda y_f.\ y \bullet praised_f \bullet x\,,$ $\lambda x_e.\lambda y_e.\lambda \mathsf{e}_e.\mathbf{praise}^{ND}_{et}(\mathsf{e}) \wedge \textsc{ag}(\mathsf{e}, y) \wedge \textsc{pt}(\mathsf{e}, x)\,\rangle$
	$\mathtt{DANCING}^{ND}$		$\mathtt{n}$	$\langle f\,,\, et\rangle$	$\langle dancing_f\,,\ \mathbf{dance}^{ND}_{et}\rangle$
E.	$\mathtt{SINK}_{unacc}$		$\mathtt{np} \to \mathtt{vp}$	$\langle\, ff\,,$ $e(et)\,\rangle$	$\langle\, \lambda y_f.\ y \bullet sank_f\,,$ $\lambda y_e.\lambda \mathsf{e}_e.\mathbf{sink}_{et}(\mathsf{e}) \wedge \textsc{pt}(\mathsf{e}, y)\,\rangle$
	$\mathtt{SINK}_{tv}$		$\mathtt{np} \to (\mathtt{np} \to \mathtt{vp})$	$\langle\, f(ff)\,,$ $e(e(et))\,\rangle$	$\langle\, \lambda x_f.\lambda y_f.\ y \bullet sank_f \bullet x\,,$ $\lambda x_e.\lambda y_e.\lambda \mathsf{e}_e.\mathbf{sink}_{et}(\mathsf{e}) \wedge \textsc{ag}(\mathsf{e}, y) \wedge \textsc{pt}(\mathsf{e}, x)\,\rangle$
	$\mathtt{SINK}_{pass}$		$\mathtt{np} \to \mathtt{vp}$	$\langle\, ff\,,$ $e(et)\,\rangle$	$\langle\, \lambda y_f.\ y \bullet was_f \bullet sunk_f\,,$ $\lambda y_e.\lambda \mathsf{e}_e.\mathbf{sink}_{et}(\mathsf{e}) \wedge \textsc{pt}(\mathsf{e}, y) \wedge (\exists x_e.\textsc{ag}(\mathsf{e}, x))\,\rangle$
	$\mathtt{BY}$		$\mathtt{np} \to (\mathtt{vp} \to \mathtt{vp})$	$\langle\, f(ff)\,,$ $e((et)(et))\,\rangle$	$\langle\, \lambda v_f.\lambda u_f.u \bullet by_f \bullet v\,,$ $\lambda v_e.\lambda A_{et}.\lambda \mathsf{e}_e.A(\mathsf{e}) \wedge \textsc{ag}(\mathsf{e}, v)\,\rangle$

Replacing Davidsonian Part B’ of Table 2 by the neo-Davidsonian Part B” of Table 3 leads to the analysis (22) of sentence (20). Note that Table 3 uses the same abstract types as in our Davidsonian analysis (18) of sentence (20). Hence the only difference between the derivation (18) and the neo-Davidsonian derivation (22) is in the lexical analysis of the sign for the verb *dance*.

(22) $\mathtt{EC}((\lambda U.\mathtt{B}_{adv}(\mathtt{D}^{ND}(U)))(\mathtt{J})) : \mathtt{s}$

$$= \langle\, (\lambda z_f.z)((\lambda u_f.(\lambda x_f.\ x \bullet beautifully_f)((\lambda y_f.\ y \bullet danced_f)(u)))(john))\,,$$
$$(\lambda E_{et}.\exists \mathsf{e}_e.E(\mathsf{e}))((\lambda u_e.(\lambda A_{et}.\lambda x_e.A(x) \wedge \mathbf{beautiful}_{et}(x))$$
$$((\lambda y_e.\lambda \mathsf{e}_e.\mathbf{dance}^{ND}_{et}(\mathsf{e}) \wedge \textsc{ag}(\mathsf{e}, y))(u)))(\mathbf{john}_e))\,\rangle$$
$$= \langle\, john \bullet danced \bullet beautifully\ ,\ \exists \mathsf{e}.\mathbf{dance}^{ND}(\mathsf{e}) \wedge \textsc{ag}(\mathsf{e}, \mathbf{john}) \wedge \mathbf{beautiful}(\mathsf{e})\,\rangle$$

Similarly, instead of the Davidsonian analysis (21) of sentence (20b), we get the neo-Davidsonian analysis in (23) below.

(23) $(\mathtt{SOME}(\mathtt{B}(\mathtt{DANCING}^{ND})))(\mathtt{EXIST}) : \mathtt{s}$

$$= \langle\, (\lambda u_f.\lambda V_{ff}.V(some_f \bullet u))((\lambda x_f.beautiful_f \bullet x)(dancing_f))(\lambda y_f.y \bullet existed_f)\,,$$
$$(\lambda U_{et}.\lambda V_{et}.\exists r_e.U(r) \wedge V(r))((\lambda A_{et}.\lambda x_e.A(x) \wedge \mathbf{beautiful}_{et}(x))(\mathbf{dance}^{ND}))(\lambda y_e.\top)\,\rangle$$
$$= \langle\, some \bullet beautiful \bullet dancing \bullet existed\ ,\ \exists r.\mathbf{dance}^{ND}(r) \wedge \mathbf{beautiful}(r)\,\rangle$$

Thus the entailment from sentence (20) to sentence (20b) is explained in the neo-Davidsonian approach without the Davidsonian lexical postulate that every *dancing* must have an agent. Such an assumption may be encoded in the neo-Davidsonian lexicon if the postulate is to be described.

A more substantial difference between the Davidsonian and the neo-Davidsonian approaches surfaces when we consider the relations between active, passive and unaccusative verbal meanings. Consider for instance the following sentences.

(24) John sank the raft.

(25) The raft was sunk by John.

(26) The raft was sunk by someone (or something).

(27) The raft was sunk.

(28) The raft sank.

Consider now the following entailments between these sentences:

(24) $\Leftrightarrow$ (25) $\substack{\Rightarrow \\ \not\Leftarrow}$ (26) $\Leftrightarrow$ (27) $\substack{\Rightarrow \\ \not\Leftarrow}$ (28)

The Davidsonian approach can treat the intransitive (unaccusative) and transitive occurrences of the verb *sink* in (28) and (24) similarly to its treatment of the verbs *dance* and *praise* in Table 2. The entailment from (24) to (28) can be described using a meaning postulate on the denotations for the two verb entries. However, the relation between active sentences and passive sentences poses a harder challenge for the Davidsonian approach. A simple passive sentence like (27) makes an existential claim about the missing agent argument (wit. the equivalence (27)$\Leftrightarrow$(26)). At the same time, the treatment of the passive should allow adding the missing agent using a *by* phrase modifier (wit. (25)). The existential import of passive constructions, together with their modifiability by *by*-phrases, are not easy to treat in Davidsonian frameworks.

The neo-Davidsonian approach allows adding arguments using the AG and PT functions. Consider how it is done in our definition of the s-interpretation of the sign BY:

$$\lambda v_e.\lambda A_{et}.\lambda \mathsf{e}_e.A(\mathsf{e}) \wedge \text{AG}(\mathsf{e}, v)$$

The v argument of the *by* phrase is connected to event argument e of the verb denotation using the AG function. This leads to the correct analysis of sentence (25) in (29) below, while retaining an existential analysis (30) of sentence (27). Note that the passive form *was sunk* is modeled as involving an implicit existential quantifier over the missing agent. When no *by* phrase is attached to the passive form, as in (27), this leads to the claim in (30) about existence of an agent. Adding a *by* phrase as in (25) instantiates the agent slot as in (29).[15]

[15] When the *by*-phrase contains a quantifier, as in, e.g. *the raft was sunk by nothing*, the existential quantifier in the passive must be intuitively interpreted in the scope of this quantifier. This agrees with our ACG treatment of this sentence, which interprets it as equivalent to *the raft was not sank*.

(29) $\mathsf{EC}((\mathsf{BY}(\mathsf{J}))(\mathsf{SINK}_{pass}(\mathsf{R}))) : \mathsf{s}$

$$= \langle\ (\lambda z_f.z)(((\lambda v_f.\lambda u_f.u\bullet by_f\bullet v)(john_f))((\lambda y_f.y\bullet was_f\bullet sunk_f)(the_f\bullet raft_f)))\ ,$$
$$(\lambda E_{et}.\exists \mathsf{e}^1_e.E(\mathsf{e}^1))(((\lambda v_e.\lambda A_{et}.\lambda \mathsf{e}^2_e.A(\mathsf{e}^2) \wedge \mathrm{AG}(\mathsf{e}^2, v))(\mathbf{john}_e))((\lambda y_e.\lambda \mathsf{e}^3_e.\mathbf{sink}_{et}(\mathsf{e}^3)$$
$$\wedge\ \mathrm{PT}(\mathsf{e}^3, y) \wedge (\exists x_e.\mathrm{AG}(\mathsf{e}^3, x)))(\mathbf{r}_e)))\ \rangle$$
$$= \langle\ the\bullet raft\bullet was\bullet sunk\bullet by\bullet john\ ,\ \exists e^1.\mathbf{sink}(e^1) \wedge \mathrm{PT}(e^1, \mathbf{r}) \wedge \mathrm{AG}(e^1, \mathbf{j})\ \rangle$$

(30) $\mathsf{EC}(\mathsf{SINK}_{pass}(\mathsf{R})) : \mathsf{s}$

$$= \langle\ (\lambda z_f.z)((\lambda y_f.y\bullet was_f\bullet sunk_f)(the_f\bullet raft_f))\ ,$$
$$(\lambda E_{et}.\exists \mathsf{e}^1_e.E(\mathsf{e}^1))((\lambda y_e.\lambda \mathsf{e}^2_e.\mathbf{sink}_{et}(\mathsf{e}^2) \wedge \mathrm{PT}(\mathsf{e}^2, y) \wedge (\exists x_e.\mathrm{AG}(\mathsf{e}^2, x)))(\mathbf{r}_e))\ \rangle$$
$$= \langle\ the\bullet raft\bullet was\bullet sunk\ ,\ \exists e^1.\mathbf{sink}(e^1) \wedge \mathrm{PT}(e^1, \mathbf{r}) \wedge (\exists x.\mathrm{AG}(\mathsf{e}^1, x))\ \rangle$$

There are open issues regarding the treatment of passive sentences, not least of them the syntactic restrictions on *by*-phrases. For instance, in a full fragment we would need to rule out questionable sentences like *the raft sank by John*. Our current neo-Davidsonian proposal incorrectly treats such illicit sentences as equivalent to the passive construction *the raft was sunk by John*. We have to defer the ACG analysis of this problem and similar ones to further research.

6 Conclusions

This paper has shown a simple treatment of events within ACG. We have shown that using the separation between the pheno-level and the semantic level within ACG it is possible to treat event arguments as purely sematic, similar to the semantic argument of nominals. This immediately accounts for the compositional restrictions on the interpretation of event modifiers and quantifiers, despite the very general treatment of scope interactions in ACG, using the Hypothetical Reasoning of the Lambek-Van Benthem Calculus. No specific assumptions were needed about the compositional working of events besides the Davidsonian assumptions about an event argument of verbs and an existential closure operator. Further, we have shown how a simple Davidsonian ACG can be modified into a neo-Davidsonian treatment, which easily captures basic facts about nominalization and passive constructions. Further research should explore the ACG treatment of existential closure operators in a dynamic setting, as well as many other remaining problems about the interplay between syntax and semantics in ACG. However, we believe that our approach to event composition can be extended to achieve better linguistic adequacy and comprehensiveness, without compromising the theoretical elegance of ACG and other work in the tradition of Categorial Grammar with Montagovian semantics.

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