The Influence of Plural NPs on Aktionsart in DRT

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Abstract. We investigate Aktionsart phenomena connected to sentences with plural NPs and spell out a definition of Aktionsarten that also applies to sentences that describe sums of events. We develop an algorithm that constructs *Discourse Representation Structures* (DRSs) from sentences and that incorporates an Aktionsart calculus that is based on the Aktionsart definition presented. Defining Aktionsarten as properties of the extension of event types in interpreting models, we explain how different readings of plural NPs - we consider the collective reading and specific distributive and cumulative readings - modify the Aktionsart by keeping track of how they compositionally contribute to the event description and what the structural effects are on the extension of the description.

1. Introduction

Since Vendler's analysis in (Vendler 1967) it is common to distinguish four classes of natural language event descriptions, *states, activities, accomplishments* and *achievements*. In terms of interval semantics these classes are normally characterized as follows:

- *States* are temporally extended and homogeneous. If a state holds at an interval t, it also holds at all subintervals t' of t (even at the time points of t, if the logic considered uses time points). This means that states have the *subinterval property* (cf. (Bennett and Partee 1972)).
  Examples are *Paul speaks French* or *Paul is eating an apple.*
- *Activities* are temporally extended and relatively homogeneous. The subinterval property seems to be restricted to subintervals that pass a *certain limit in size* (cf. (Dowty 1986)).
  An example is *Paul worked in the garden.*
- *Accomplishments* are temporally extended and heterogeneous, i.e. if an accomplishment holds at an interval t, it does not hold at the subintervals of t. This is true of *Paul wrote a letter*, for example.
- *Achievements* are punctual: *Paul reached the top.*

Following a linguistic tradition referred to in (Steinitz 1981), we call this classification a classification of the *Aktionsart* of events or event descriptions.[1]

Vendler presents linguistic tests for the determination of the Aktionsart of event descriptions. Activities and states can co-occur with adverbials like *for three hours* but not (at least not without changing the 'normal' meaning of the description) with adverbials like *in three hours*. For accomplishments it is the opposite. The co-occurrence test with *in*- and *for*- adverbials marks a distinction of Aktionsarten that is of decisive importance with respect to a wide range of textual behavior: the distinction between *homogeneous* and *heterogeneous* event descriptions.[2]

It is not the verb alone which decides the Aktionsart of the event introduced by a sentence. The different thematic roles influence the choice. Thus, for instance,

(1) *Peter drank.*

refers to an activity. We can easily say *Peter drank for several hours.* Adding information to (1) about the object consumed can confirm the Aktionsart of (1), as in (2):

(2) *Peter drank beer. / Peter drank cocktails.*

But it can also result in a change of the Aktionsart, as in (3):

(3) *Peter drank a glass of beer.*

Again the in/for-test points up the difference between (2) and (3).

It is often said that bare plurals (and also mass terms) uniformly transform accomplishments and achievements into activities. Calculi that compute the Aktionsart and that treat the influence of bare plural roles in this uniform way using syntactically and/or morphologically motivated feature descriptions of the roles were suggested by (Verkuyl 1972), (Platzack 1979) and (Reyle 1987) among others. We think however that, first, the influence of bare plural roles on the Aktionsart is not unique and, second, that this influence must be described in terms of explanatory semantic criteria. We think that this is also true of other role descriptions. However, in this paper we will concentrate on how descriptions of thematic roles that denote sets contribute to the Aktionsart of the entire clause. Here, we will restrict ourselves to German sentences.

(4) a. *Sportler brachten die olympische Fackel nach Barcelona.*
(Sportsmen took the olympic torch to Barcelona.)

b. *Olympia-Fans fuhren nach Barcelona.*
(Olympics fans went to Barcelona.)

c. *Beim Stürmer-Training drosch Völler Bälle ins Tor.*
(At the forward training, Völler kicked balls into the goal.)

d. *Am Mittwoch transportierte ein FIFA-Mitarbeiter Bälle von London nach Rom.*
(On Wednesday, a FIFA-employee carried balls from London to Rome.)

Provided the reading is chosen that, against the background of world knowledge, is most natural, (4a) and (4d) are accepted in the scope of (pragmatically suitable) in-adverbials, whereas (4b) and (4c) are not. With respect to for-adverbials, we observe the opposite behavior. [3] So the test with in- and for-adverbials corroborates the preferred reading in (4a) and (4d) as an accomplishment, and as an activity in

(4b) and (4c). This does not correspond to the outcome of analytic systems such as the ones mentioned above that attribute uniform Aktionsart effect to bare plurals.

Often, the use of a bare plural phrase turns a sentence into a generic statement: For instance, the transition *the car has four wheels* $\rightarrow$ *cars have four wheels* turns the situation dependent statement about a concrete object *car* into a generic statement about the *kind* CAR. Generic statements, of course, are stative. Clearly, none of the examples of (4) is a generic statement. In this paper, we will not consider the use of bare plurals in generic sentences. We will treat only cases like (4), with situation dependent interpretation and bare plurals that refer to sums or sets of objects, not to kinds (or at least , also to sums or sets and not exclusively to kinds (cf. (Carlson 1980))).

We will try to explain the diverging impact of plural phrases onto the Aktionsart of the correspondingly modified event descriptions by extending an approach of Krifka's (cf. (Krifka 1987b)). For Krifka, the different Aktionsarten of sentences rely on different structural properties that the extensions of the event predicates of the sentences have in interpreting models. Krifka's approach is an elaborate reformulation of Vendler's point of view within a framework with reified events. We deviate from Krifka's approach in that we also consider event types that describe sets or sums of events (normally introduced via iteration or via summing up the events introduced by quantification over thematic roles). This modification extends, as we think, the fragment with which we can correctly deal with respect to semantic representation and Aktionsart computation. In particular, it allows for a correct, unified account of (4), which, otherwise, to our opinion, can be only fragmentarily evaluated.

Roughly, on this structural basis, we think that in (4a) - (4d) the bare plural phrases uniformly introduce a set or sum of individuals each (with identical ontological status, i.e. without a distinction of the type *kind, object*). In our opinion, the Aktionsart difference derives from the fact that with *fahren nach Barcelona* in (4b) and *Völler ins Tor dreschen* in (4c) the distribution over the set is preferred (over *Olympia-Fans* in (4b) and over *Bälle* in (4c)), and that with *die olympische Fackel nach Barcelona bringen* and *ein FIFA-Mitarbeiter von London nach Rom fahren* the distribution over the set (*Sportler* in (4a) and *Bälle* in (4d)) is not licensed or, at least, is not preferred. Since, more specifically, we assume in the distributional case some 'distribution in time', the downward heredity, that is typical of activities or states, is guaranteed for (4b) and (4c), provided we make use of a suitable refined notion of homogeneous Aktionsart that includes the evaluation of event types that refer to event sums. (Assuming for (4c) that there is an unknown number of balls hit into the goal one after the other over a certain time t, for subintervals t' of t, we observe the same (specific) property, and accordingly for (4b)).

In order to characterize this conception within a formal theory, we will proceed in the following way. The background of our formalization will be *Discourse Representation Theory* (henceforth DRT, cf. (Kamp 1981)). In the next section we introduce the concepts of this theory that are relevant to our subject. This includes extensions of the DRT-language where needed. On the basis of this, we will motivate and define in section 3 a refined notion of homogeneous and heterogeneous event types that is also applicable to types that refer to sums of events. In section 4 we will sketch a DRS-construction algorithm for collective and distributive readings which comprises an Aktionsart calculus. In section 5 we will extend this algorithm to allow for cumulative readings. This extension gives a means for fine-tuning the construction of the desired representations of (4) and of other plural constructions. In the concluding section 6 we summarize the results of the suggested formal treatment.

The approach described in this paper is a condensed, updated version of some aspects of the broader approach developed in (Eberle 1991).

2. Representations and Model Theory

In the framework of Discourse Representation Theory (DRT) (Kamp 1981) a DRS is a pair $< U, K >$ consisting of a set U of discourse referents (DRFs) and a set K of conditions. Since the beginnings of DRT in 1981 several types of conditions have been introduced. (For a recent version of DRT, compare (Kamp and Reyle 1993)). For the purposes of this paper, we will utilize the set of condition types presented below. As in (Eberle 1991) and in (Kamp and Reyle 1993), a semi lattice approach has been adopted in order to model plural phenomena of natural language texts. There are several reasons motivating such an approach that we will not, however, go into here. [4] So conditions may take the following forms reflecting the lattice structuring of the domain of models:

1.) $P(a_1, \ldots, a_n)$, where P is an n-ary predicate symbol and the a_i are discourse referents. For 2-place relations we will also use infix notation. Among other things the two-place relations used are $\in_i, \leq_i$ and $<_i$, standing in turn for *atomic part, part* and *part proper.*

2.) $P^*(a)$, where P is a one-place predicate symbol, a is a discourse referent and * an operator defined for one-place predicate symbols, the *plural operator*, which, with respect to a particular interpretation, when applied to P, denotes the sums that can be constructed from the objects denoted by P.

3.) $f(a_1, \ldots, a_n) = a$, where f is an n-ary function symbol and $a_1, \ldots, a_n, a$ are discourse referents. Among other things we will use one-place functions for particular thematic roles of events like *agent, theme, object* and the two-place function $\sqcup_i$ which is used to construct the sum of discourse referents. Conditions of the three forms described are also called *atomic* conditions.

4.) $K_1 \langle \substack{\text{every} \\ x} \rangle K_2$, where K_1, K_2 are DRSs and x is a discourse referent introduced in the universe of K_1. Conditions of this form are also called *duplex* conditions. They reflect universal quantification over the x satisfying the conditions of K_1. K_1 is called the *restrictor* and K_2 the *nuclear scope* of the duplex condition. (There are other duplex conditions, which are of no interest here.)

5.) $z = \Sigma y K$, where K is a DRS, y a DRF of $U(K)$ and z a DRF which stands for - with respect to a particular interpretation I - the sum of those objects o for which K is valid with respect to some I' that develops from I by assigning o to y. We say that we get z via *abstraction* from K.

6.) $(\lambda y K)(z)$, where K is a DRS, y a DRF of $U(K)$, and z a DRF the *defined property* $\lambda y K$ is predicated of.

We require the domain of a model of a DRS to be a complete and complementary join semi lattice.

A1	$\forall x, y \quad (x \sqcup_i y = y \sqcup_i x)$	commutativity
A2	$\forall x \quad (x \sqcup_i x = x)$	idempotence
A3	$\forall x, y, z \quad (x \sqcup_i (y \sqcup_i z) = (x \sqcup_i y) \sqcup_i z)$	associativity
A4	$\forall x, y \quad \exists^{=1} z \quad (x \sqcup_i y = z)$	totally defined function
A5	$\forall x, y \quad (x \leq_i y \leftrightarrow x \sqcup_i y = y)$	part
A6	$\forall x, y \quad (x <_i y \leftrightarrow x \leq_i y \wedge \neg x = y)$	proper part
A7	$\forall x, y \quad (x \circ_i y \leftrightarrow \exists z (z \leq_i x \wedge z \leq_i y)$	overlap
A8	$\forall x, y \quad (x <_i y \rightarrow \exists^{=1} z (\neg x \circ_i z \wedge x \sqcup_i z = y))$	complementarity

An important subset of the domain is, of course, the class of atoms.

A9 $\forall x \quad (atom(x) \leftrightarrow \neg \exists y (y <_i x))$
A10 $\forall x \exists y \quad (y \leq_i x \wedge atom(y))$

Generalizing $\sqcup_i$ to sup_i which denotes the function that, for any set B of the domain, returns the least upper bound of the elements of B with respect to $\leq_i$, we can characterize the functionality of the operator *:

A11 $\forall B \exists x \quad (sup_i(B) = x)$
A12 $\forall P \forall x \quad (P^*(x) \leftrightarrow \exists B \ (B \subseteq P \wedge x = sup_i(B)))$

A8-A11 (together with the other axioms) guarantee that the lattice structuring reflects the relevant properties of set theory with respect to its use in natural language. The possibility of defining 'elements' emphasizes this:

A13 $\forall x, y (x \in_i y \leftrightarrow x \leq_i y \wedge atom(x))$

In order to restrict the set of structures suited for the interpretation of DRSs, here, we have used formulae of predicate calculus. This has been done for the sake of brevity only. Of course, using DRSs, we can characterize the same set of suitable interpreting structures. (Therefore, however, we need a condition type, omitted here, which expresses the negation of a statement). Since we want to develop a theory of event descriptions within the framework of DRT, throughout this paper we will consider formulae of predicate calculus as abbreviations of corresponding DRSs.

Now, for K a DRS, and M a model with interpretations for the predicate- and function-symbols, $\hat{f}$ a partial embedding function from the set of DRFs onto the domain of M, we say that $\hat{f}$ verifies K in M iff $M \models_{\hat{f}} K$, where:

$M \models_{\hat{f}} K$ iff $\hat{f}$ is defined for the DRFs of $U(K)$ and $M \models_{\hat{f}} C(K)$.
$M \models_{\hat{f}} C(K)$ iff for all $c \in C(K)$ $M \models_{\hat{f}} c$.
For $M \models_{\hat{f}} c$, corresponding to the different types of condition, we stipulate that:

I.1) $M \models_{\hat{f}} P(a_1, \ldots, a_n)$ iff $P^M(\hat{f}(a_1), \ldots, \hat{f}(a_n))$

I.2) $M \models_{\hat{f}} P^*(a)$ iff there exists $B \subseteq P^M$ with $sup_i^M(B) = \hat{f}(a)$

I.3) $M \models_{\hat{f}} f(a_1, \ldots, a_n) = a$ iff $f^M(\hat{f}(a_1), \ldots, \hat{f}(a_n)) = \hat{f}(a)$

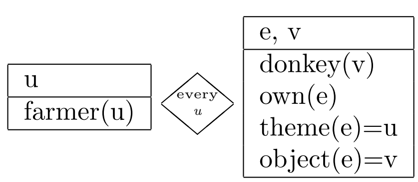
I.4) $M \models_{\hat{f}} K_1 \langle \text{every}_x \rangle K_2$ iff there exists an extension $\hat{g}$ of $\hat{f}$, DRFs x_1 and x_2 with $x_1, x_2 \notin def(\hat{f})$ such, that from $M \models_{\hat{g}} x_1 = \Sigma x K_1$ and $M \models_{\hat{g}} x_2 = \Sigma x(K_1 \bigcup K_2)$ it follows that $\hat{g}(x_1) = \hat{g}(x_2)$.

I.5) $M \models_{\hat{f}} z = \Sigma y K$ iff $\hat{f}(z) = sup_i^M(A)$,
where $A = \{a \mid$ there exists $\hat{g}$ that extends $\hat{f}$ onto $U(K)$ with $M \models_{\hat{g}} K$ and $a = \hat{g}(y)\}$

I.6) $M \models_{\hat{f}} (\lambda y K)(z)$ iff $\lambda y K$ is a *defined predicate* with respect to the interpretation $< M, \hat{f} >$ and $\hat{f}(z) \in |[\lambda y K]|_{M,\hat{f}}$, where
$\lambda y K$ is a *defined predicate* with respect to the interpretation $< M, \hat{f} >$ iff $\hat{f}$ is defined for the *free variables* of K. In this case we stipulate that
$|[\lambda y K]|_{M,\hat{f}} = \{a \mid$ there exists $\hat{g}$ that extends $\hat{f}$ onto $U(K)$ with $M \models_{\hat{g}} K$ and $a = \hat{g}(y)\}$.
We call a DRF x a free variable of K iff x is contained in an atomic condition C of $C(K')$, with K' a sub-DRS of K, but is neither element of $U(K')$ nor element of the universe of a sub-DRS of K that contains K'. (Of course, K is a sub-DRS of itself).

It is clear, first, that we will use duplex conditions in order to represent natural language statements like (5)

(5) *Every farmer owns a donkey.*

(5_{rep})


Second, we use abstraction type conditions in order to be able to refer to sums that can be abstracted from conditions like (5_{rep}):

(6)

<table>
<tr><td colspan="2">U</td></tr>
<tr><td>U = Σ u</td><td><table><tr><td>u, e, v</td></tr><tr><td>farmer(u)
donkey(v)
own(e)
theme(e)=u
object(e)=v</td></tr></table></td></tr>
</table>

In (6), U stands for the sum of those farmers who own at least one donkey. Exchanging U for V and the u after Σ for v in (6) would provide us with a DRF V referring to the sum of those donkeys that are owned by a farmer.

In (6) we have used the convention that upper case letters are DRFs that denote sums of objects, and that lower case letters are DRFs that denote atomic objects.[5]In addition, in the following, we will use greek letters as DRFs that are underdetermined with respect to their reference to atomic or non-atomic objects. For the abstraction of sums from duplex conditions, we allow for the following abbreviation:

$\chi_{i_1}, \ldots, \chi_{i_n}$ :: <table><tr><td>$K_1 \langle ? \rangle K_2$</td></tr></table>

replaces

$K_1 \langle ? \rangle K_2$

$\chi_{i_1} = \Sigma \chi_{i'_1} (K_1 \bigcup K_2)$

$\vdots$

$\chi_{i_n} = \Sigma \chi_{i'_n} (K_1 \bigcup K_2)$

where $\chi_{i'_1}, \ldots, \chi_{i'_n} \in U(K_1) \bigcup U(K_2)$

In order to establish unique reference between the DRF of the sum and the DRF for the objects that make up this sum we use indices: Y_1 sums up y_1, X_7 x_7, χ_3 χ'_3, and so forth. Another notational convenience is the following. We use:

<table>
<tr><td>(M)</td></tr>
<tr><td>(M) :: <table><tr><td>$K_1 \langle ? \rangle K_2$</td></tr></table></td></tr>
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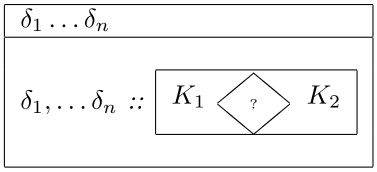
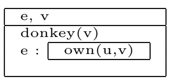
as shorthand for



where the set of δ_i, i.e. (M), exhausts the possibilities for abstraction with respect to the corresponding duplex condition. This means that there are $\delta'_1, \ldots, \delta'_n$ the δ_i abstract over in turn such that $\{\delta'_1, \ldots, \delta'_n\} = U(K_1) \bigcup U(K_2)$.

DRT uses a variant of the Davidsonian method of talking about events (Davidson 1967) and treats them as a kind of objects. While we have adopted this, we deviate from the usual DRT-style representation of event descriptions according to which, for instance, the nuclear scope box of (5_{rep}) would be written as follows:



For representing event descriptions, in classical DRT, complex conditions are introduced which are pairs consisting of the DRF for the event, and of a DRS containing the event description in terms of an n-ary event predicate over the DRFs of the thematic roles. Instead of this, (compare the original nuclear scope box of (5_{rep})), we use one-place event predicates and a number of explicit one-place functions corresponding to the thematic roles which allow for relating the values of the thematic roles to the event. (Since we use this alternative notation, above, we have omitted to list the usual condition type of DRT for event descriptions). We abstain from the DRT style in this respect and use one-place event predicates and explicit thematic roles for reasons presented, for instance, in (Bäuerle 1988) and (Krifka 1987b). We will not go into detail with this here. We only mention that the existence of verbs which do not show up any syntactically subcategorized obligatory thematic role (e.g. verbs like *raining, storming* with expletive subject) and the relatively autonomous status of thematic roles (*the agent, the (consumed) object* (of an eating event)) seem to support the choice made. In addition, this notation facilitates linking up with KL-ONE like knowledge representation formalisms.[6] Concluding this section we would like to stress that within DRT (and accordingly in this paper) DRFs introduced by descriptions of events proper and DRFs introduced by state descriptions like the *owning* in (5_{rep}) both refer to elements of the domain of a model that are not purely temporal objects (like time points or time intervals).[7] The defined predicates of the condition type 6.) will be used mainly with regard to event-DRFs. In this case they represent event types. [8]

3. Homogeneous and Heterogeneous Event Types

Our concern is to classify event types by means of structural properties of their extensions in the model. Therefore, we will develop some helpful notions. This will be done mainly by using predicate calculus characterizations. But, as mentioned in the last section, these characterizations can be taken as shorthand for corresponding DRT-statements.

We do not classify events, but event types. Consider the following pair of sentences (and the very similar examples (1)- (3)):

(7) a. *Peter trank Wein.*
(Peter drank wine.)
b. *Peter trank ein Glas Wein.*
(Peter drank a glass of wine.)

(7a) is a homogeneous and (7b) a heterogeneous description, as the test with in- and for-adverbials makes clear. Since, with respect to a specific model, (7a) and (7b) might nevertheless be alternative descriptions of the **same** event, it is clear that the different Aktionsarten cannot be properties of the events themselves, but must be properties of the event types. This is also the standpoint of (Krifka 1987b), (Krifka 1987a). We will postpone discussing Krifka's relevant explication of how the thematic roles compositionally influence the Aktionsart of the entire description in cases like (7a) and (7b) until the end of this section. In the following, for the purpose of investigating suitable notions of homogeneity, we can do with considering the descriptions as not further analyzed predicates. Krifka assumes the domain of a model for a natural language sentence or text to be structured by means of a two-place fusion operation, $\sqcup$, as a semi lattice. We stress that Krifka's semi lattice structuring has weaker properties than our structuring of the last section. So, for instance, it does not make sense to attribute a numerical value to Krifka's objects which could reflect the cardinality of the set of atoms that such objects subsume, since normally there is no unique partition of an object into atoms. In our modelling, there is. Here the relation $\leq_i$ exclusively reflects the $\subseteq$-relation of set theory, and not the more general part-relation of mereology as Krifka's $\leq$ does. For this reason, we call Krifka's lattice operation *fusion* and not *sum operation*.

With respect to the dichotomy that the in/for-contrast makes explicit, the relevant distinction for Krifka is the distinction between *cumulative* and *quantized* predicates or, more generally, that between *cumulative* and non-cumulative predicates, rather than that between *divisive* and non-divisive predicates. Using $\sqcup$ and $\leq$, cumulativity and divisivity are defined as follows:
A property P is cumulative, $KUM(P)$:
iff

$$\forall x, x' \quad (P(x) \wedge P(x') \rightarrow P(x \sqcup x'))$$

and a property P is divisive, $DIV(P)$:
iff

$$\forall x, x' \quad (P(x) \wedge x' \leq x \rightarrow P(x'))$$

The DIV/nonDIV-distinction would fit better with the more traditional picture of the 'downward looking' subinterval property that we presented in the introduction. Krifka's argument against the latter distinction is the incomplete homogeneity that activities normally show at their lower periphery. *Working*, for example, is understood as divisive though realizations of *working* can contain periods where the activity of working is suspended, and though there is a vague natural temporal threshould such that it does not make sense to call subperiods of a *working* that are below this threshould periods of working. For instance, periods that measure some nanoseconds might show some of the constitutive subactivities that make up walkings, but they never can be called periods of walking. These problems of pauses and perception limits have led Dowty and others to weakening the requirements of homogeneity for activities, what resulted in weak divisivity based definitions of activities, like the one sketched in the beginning of this paper. Such definitions necessarily lack the precision, naturalness and simplicity of the canonical definition of the cumulative reference. Nevertheless we think that divisivity is the decisive feature, or to be more precise, that the definition of homogeneity that classifies the data in a linguistically correct way cannot separate cumulativity from divisivity. In order to motivate this, we will use the test with in- and for-adverbials. The criterion that predicts and structurally explains the combinatory behavior of event descriptions in this respect must play a central role in a structural theory about Aktionsarten. Consider the following critical examples:

(8) *a.* *Petra arbeitete im Garten.*
(Petra worked in the garden.)
b. *Die Maschine sendete Licht aus.*
(The machine emitted light.)
c. *Paola streichelte einen Hund.*
(Paola caressed a dog.)
d. *Paola streichelte (gleichzeitig) zwei Katzen.*
(Paola caressed two cats (simultaneously).)
e. *In München aß Peter eine Schweinshaxe mit Sauerkraut.*
(In Munich, Hans ate a trotter with sauerkraut.)
f. *Der Roboter bewegte sich höchstens 50 Meter vorwärts.*
(The robot moved forward at most 50 meters.)
g. *Der Roboter bewegte sich mindestens 50 Meter vorwärts.*
(The robot moved forward at least 50 meters.)
h. *Die Bombe explodierte.*
(The bomb exploded.)

As the test with in- and for-adverbials shows, (8a) - (8d) are homogeneous event descriptions, whereas (8e) - (8h), with respect to the normal, non-iterative reading, are not. The formal definition of homogeneity to develop must account for this behavior.

All sentences of (8) describe single events. We concentrate on this case first, i.e. on the case of predicates whose extension contains only single events.

Our modelling does not yet contain a structuring of the domain of single events. We introduce the mereological *material part*-relation $\leq_m$ (that corresponds to Krifka's $\leq$):

• $\leq_m$, the *material part* relation structures the domain of a model as a preorder. It extends the subsum relation $\leq_i$, i.e it holds that $\forall x, y \quad (x \leq_i y \rightarrow x \leq_m y)$, but it does not hold that $\forall x, y \quad (x \leq_m y \rightarrow x \leq_i y)$.[9]

From $\leq_m$ we define the *material equivalence*:

• $\forall x, y \quad (x =_m y \leftrightarrow x \leq_m y \wedge y \leq_m x)$.

By materially equivalent events we mean events which are identical with respect to some coarse-grained notion of (physically motivated substantial) identity, for instance, in the sense of spatio-temporal regions. Nevertheless, such events may be different with respect to the level we are mainly concerned with here, which is a rather fine-grained ontological level suited for interpretations of natural language texts.[10]

Now, we call e' a *subevent* of e iff $e' \leq_m e$.

Above we have mentioned the problem of pauses and threshoulds connected to activities like those described by (8a) and (8c). In order to restrict the test for divisivity to the relevant subevents of an investigated event, we make use of the following concepts:

• *lz* (for *Laufzeit*/*run time*) applied to an event e of a particular event type (of *working*, for instance), returns the time period (which is not necessarily an interval) at which the active phases of e (the phases of uninterrupted working) occur.

• *limit* applied to an event predicate P returns the threshould value that is specific for P. This value is given in terms of a measure for the substance of events, for instance, it is measured with respect to some spatio-temporal scale. [11]

• *size* applied to an event returns the volume of the event in terms of the scale used for *limit*.[12]

• *max-t-auss* (for **max***imaler* **t***emporaler* **Auss***schnitt*/*maximal temporal segment*) holds for triplets $(\bar{e}, t, e)$, where t is a subinterval of the time at which e occurs and $\bar{e}$ is a maximal subevent of e (in the sense of $\leq_m$) occurring at t, i.e $\bar{e}$ is a maximal temporal segment of e with respect to t.

Now, we call an event predicate P divisive:

(I) DIV(P) iff for each event e of its extension and for each *maximal temporal segment* $\bar{e}$ of e that is temporally located within the *run time* of e and that is voluminous enough in *size* in order to pass the specific *perception limit* for P-events, there exists an event e' that is materially equivalent to $\bar{e}$ and that is a P-event too.

This characterization uses *lz* in order to obtain cleaned versions, so to speak, of the events of the P-predicate. This fading out of phases that are irrelevant with respect to the event description copies the behavior of the human recipient of a text, as we think, and restricts the application of the divisivity test proper to those phases of the event that are in focus exclusively. In addition, when testing a particular P, the characterization takes into account the P-specific granularity of the P-objects. So, following (I), the event predicate of (8a) will be classified as divisive, though Petra may interrupt her activity now and then for talking to a neighbor or for drinking a glass of beer, and though the remaining active phases are not divisive, when evaluated by means of a threshould value that is suited with respect to *emitting light*-events say, as described in (8b). Of course, since the realization of the constitutive subactivities takes less time in the case of *emitting light*-events than it takes in the case of *working in the garden*-events, using the threshould value for the *emitting light*-predicate would produce a too fine-grained test for divisivity in the case of (8a).

(8d) explains why the test of (I) makes use of maximal temporal segments instead of the more general subevents. (8d) should be classified as a divisive event description. The event introduced by (8d), e_d, can be analyzed into two events, $e1_d$ and $e2_d$, where $e1_d$ is the caressing of the one of the two cats, and $e2_d$ is the caressing of the other cat. Thus, we obtain $e1_d \sqcup_i e2_d =_m e_d$ and, from this or directly, we obtain the actually relevant conditions $e1_d \leq_m e_d$, $e2_d \leq_m e_d$. $e1_d$ and $e2_d$ are material parts of e_d, i.e. they are subevents of e_d. Provided that e_d is a typical representatitve of the P-type, besides e_d, $e1_d$ and $e2_d$ will pass the threshould value for P that will be something like the volume of the smallest events of *caressing caused by a human agent*. However, neither $e1_d$ nor $e2_d$ is an event of type P: a caressing of two cats. We notice here that we obtain subevents in different ways as soon as events are understood as objects that are more than purely temporal units like intervals or time points. Material parts, subevents, can be extracted from an event by running along the time axis and segmenting the event into time slices. However, subevents can also be extracted by cutting pieces along the lines of other dimensions or even by mixed cutting procedures. It is reasonable to equip events with qualities that go beyond the scope of pure temporality (for this, compare for instance (Bäuerle 1988)), and it is reasonable to define *subevent* as a not further specified material part of an event. Notice, that, for the e_d-scenario of simultaneously caressing two cats, the definition of *subevent* as time slice, i.e. as temporal segment that exhausts the “spatial breadth” of the event, would rule out the possibility to call $e1_d$ and $e2_d$ *subevents* of e_d. Thus, if we want to dispose of something that is comparable to the subinterval property, that has been formulated within the formally simpler framework of interval semantics, with respect to our more complex event semantics, we need the concept of the maximal temporal segment. Contrasting interval semantics with the event semantics approach with material part relation, the subinterval property corresponds to the divisivity that is restricted to maximal temporal segments. (Of course, within this approach, a *temporal segment* that is not maximal is any subevent whose occurrence time is an interval). Since maximal temporal segments exhaust the “spatial breadth" of the event, both cats play a role in the maximal temporal segments of the cleaned version of a *simultaneously caressing two cats*-event. Thus, for each maximal temporal segment $\bar{e}$ of the cleaned version of a *simultaneously caressing two cats*-event e, there must exist a materially equivalent event e' ($e' =_m \bar{e}$) that is a *simoultaneously caressing two cats*-event too, provided $\bar{e}$ is voluminous enough to allow the perceptibility of such an event type for the equal-sized event e'. The test for divisivity does not require the inheritance of the event type onto $\bar{e}$ itself, since in the presence of ontologically fine-grained text models, as suggested in this paper, materially equivalent events might show divergent behavior with respect to event descriptions. For instance, though materially equivalent, e_d is a single event with

$$e_d \in \lambda \text{e} \begin{array}{|l|}\hline \text{e, paola, X} \\ \hline \text{cat*(X)} \\ \text{|X|=2} \\ \text{caress(e)} \\ \text{agent(e)=paola} \\ \text{object(e)=X} \\ \hline \end{array}$$

and $e1_d \sqcup_i e2_d$ is an event sum with

$$e1_d \sqcup_i e2_d \in \lambda \text{E} \begin{array}{|l|}\hline \text{E, paola, X} \\ \hline \text{cat*(X)} \\ \text{|X|=2} \\ \text{E ::} \begin{array}{|l|}\hline \text{x} \\ \hline \text{x} \in_i \text{X} \\ \hline \end{array} \left\langle \begin{array}{c} \text{every} \\ \text{x} \end{array} \right\rangle \begin{array}{|l|}\hline \text{e} \\ \hline \text{e} \in_i \text{E} \\ \text{caress(e)} \\ \text{agent(e)=paola} \\ \text{object(e)=x} \\ \hline \end{array} \\ \hline \end{array}.$$

Because of this, there might be some members of a class of materially equivalent, maximal temporal segments that are P-events, and others that are not, and for the latter ones the divisivity test would fail, provided P is the tested event predicate. In order to rule out this false behavior, our definition only requires that there is a representative of each of these classes of critical maximal temporal segments that has the P-quality.

It should be clear by now, that (I) will accept the examples (8a)-(8d), if they come with their natural meaning.

However, (I) will also accept (8f). If the robot moved forward at most 50 meters over the occurrence time of the event of (8f), it moved forward at most 50 meters over the occurrence time of any critical temporal segment of this event.

Nevertheless (8f) is obviously not homogeneous. (8f) is an example that illustrates the necessity of the cumulativity constraint:

We call a predicate P cumulative:

(II) CUM(P) iff for all events e, e' of the extension of P that have a *common maximal segment*, there exists an event e" that is *materially equivalent* to the sum of e and e' ($e \sqcup_i e' =_m e$") and that is an element of the extension of P too.

The *common maximal segment* is defined as follows:

• For events e, e': e and e' have a common maximal segment, i.e. $e \circ_m^{max} e'$ iff there exists an event $\bar{e}$ and an interval t with *max-t-auss($\bar{e}$,t,e)* and *max-t-auss($\bar{e}$,t,e')*.

With respect to (8f), (II) is not satisfied: there are normally overlapping events of *moving at most 50 meters*-events, that, when amalgamated, are materially equivalent to an event of *moving more than 50 meters*.

In order to preserve homgeneity for (8a)-(8d) , we have to show that these examples are cumulative. For the examples (8a) and (8b) this is rather obvious. We concentrate on the examples (8c) and (8d) which are critical in this respect. This allows for explaining the introduction of $\circ_m^{max}$. The amalgamation of two events of *Paola caressing a dog* normally returns an event of *Paola caressing two dogs*. Note, that the event predicate $\lambda e(\exists u(dog(u) \wedge caress(e) \wedge agent(e) = paola \wedge object(e) = u))$, $(= P)$, does not require that its elements have the same value of the *object* role. However, if we restrict ourselves to instances e, e' of P that have a common maximal segment for some interval t ($e \circ_m^{max} e'$), we are sure that e and e' refer to the same dog. In this case there exists an event e" which is materially equivalent to the sum of e and e' and which is an element of P. In this weak sense the P of (8c) is cumulative. We stress that using the relation of temporal overlap instead of $\circ_m^{max}$ in (II) would not be specific enough. It might be that Paola caressed a dog x at t and another dog x' at t' such that for a common time interval t" she caressed two dogs. The amalgamation of the corresponding events e and e' would result then in an event that is materially equivalent to an event of *Paola caressing two dogs*. A similar reflection which uses the example (8d) of *Paola simultaneously caressing two cats*-events shows that also the simple material overlap is not sufficient: Think of events e, e' of caressing cats a and b, and b and c respectively, that overlap in an event of caressing cat b. e" ($=_m e \sqcup_i e'$) is a caressing of three cats in this case.

(8f) has shown that divisivity as such is not a sufficient criterion for homogeneity. (8g) shows that cumulativity as such is not a sufficient criterion for homogeneity either. [13] (8g) is cumulative in the sense of (II), but not homogeneous. The treshould value for *moving*-events will be such that for normal events of *moving at least 50 meters* there are maximal temporal segments of enough volume that are materially equivalent to an event of *moving*, but that are not materially equivalent to a *moving at least 50 meters* event respectively. Thus (8g) will not satisfy (I). A similar reflection excludes divisivity for (8e) and, therefore, truly classifies it as non-homogeneous.

It remains to show the non-homogeneity of (8h). The problem of (8h) is that an *exploding*-event is normally understood as punctual, there are no maximal temporal segments that could be temporally shorter than this event, and therefore, the event description has to be understood as trivially fulfilling the divisivity constraint (I). In addition, since the extension of *the bomb exploded* consists of exactly one event, the cumulativity constraint (II) is also trivially satisfied. In order to correctly rule out homogeneity in such cases, we require:

(III) P is homogeneous only if its extension provides at least two events e and e' that have a common maximal segment, without being *material parts* of each other.

(I)-(III) cover the Aktionsart phenomena of the domain of predicates that hold for single events.

We now have to account for the case of homogeneous event descriptions that introduce a sum of events. For an illustrating example, consider the iterative use of *Peter eine Schweinshaxe essen* that develops from (8e), if (8e) is combined with a for-adverbial *for months*:

(9) *In München aß Peter monatelang eine Schweinshaxe mit Sauerkraut.*
(In Munich, Peter ate a trotter with sauerkraut for months.)

Of course, here, even our redefined subinterval property (I) is too restrictive. The threshould of *essen* is smaller than the *size* of the single *eine Schweinshaxe essen*-events. Apparently, in natural language we make use of two different levels of granularity in this respect: The one refers to realizations of the event type that is expressed by the verb. The other, more coarse-grained, refers to periodic realizations of this type. Information from the thematic roles will influence the granularity of the periodicity. [14] We use the operator *ITER* (for *iter*ation) in order to obtain the class of periodic realizations of a particular event type Q. We define *ITER* as an operator for event predicates such that

• for all event sums E and for all event predicates Q:
$ITER(Q)(E)$ iff there exists a set B with $B \subseteq Q$ and $E = sup_i(B)$ and *temp-distr(E).*

temp-distr is defined as follows.

• Let E be a sum of events, then
temp-distr(E) iff there exists a *grid* T such that for all $e \in_i E$ there exists a $t \in_i T$ with $e \oslash t$ and for all $t, t' \in_i T$ there exist $e, e' \in_i E$ with $temp(e) \neq temp(e'), e \oslash t, e' \oslash t'$.

Here, $\oslash$ stands for the temporal overlap relation, *temp* returns the time of an event. For E with *temp-distr(E)*, we say that E is **temp***orally homogeneously* **distr***ibuted*.

• For T, a sum of at least two intervals:
T is a grid, i.e. *grid(T)* iff T consists of consecutively ordered atomic intervals of equal temporal length and meeting each other.

Now, we call a predicate P homogeneous:

(IV) P is homogeneous if there is an event predicate Q such that P is materially equivalent to $ITER(Q)$.

Predicates that satisfy to (IV) are cumulative and divisive, but in a very weak sense. Such predicates P are divisive only in terms of the granularity of the instances of P. I.e., with respect to a particular instance E of P, the downward heredity of P is only required within the limits that are drawn by the segmentation of the grid that corresponds to E into subgrids: Each iterative realization E of *eine Schweinshaxe essen* determines a grid T whose mesh width depends on the frequency of the realization of the single *eine Schweinshaxe essen*-events in E. While these maximal temporal segments of E that are realized at some subgrid of T inherit the quality of being an iterative realization of *eine Schweinshaxe essen* from E, the others do not (necessarily), even if they pass the threshould for *essen*. For instance, subevents of the single *eine Schweinshaxe essen*-events of E may fulfill the threshould-condition for *essen*-events. However, they will never be iterations of *eine Schweinshaxe essen*-events.

Cumulativity is guaranteed for events (or event sums) $\varepsilon, \varepsilon'$ that share a common Q-event, since, in this case, from suited temporally overlapping grids T and T' for $\varepsilon, \varepsilon'$, we obtain a grid T" for $\varepsilon \sqcup_i \varepsilon'$ by coarsening the more fine-grained grid, T or T', to the granularity of the other, and by taking the sum of these grids: there exists E with $E =_m \varepsilon \sqcup_i \varepsilon'$, with T" is a grid of E, and $ITER(Q)(E)$.

Among other things that we concentrate on below, these weak requirements on homogeneity seem to be justified, as mentioned, by the iterative use of heterogeneous descriptions like (9) or the following example (10).

(10) *Eine halbe Stunde lang warf sich der Stuntman aus dem Fenster.*
(For half an hour the stuntman threw himself out of the window.)

As (9) and (10) make clear, in the case of for-adverbials plus iteration of a predicate P, the mesh width of the grid that is introduced depends on both the measure introduced by the adverbial, the knowledge about the typical length of P-events, and the knowledge about possible distances between P-events. In (9), the grid will consist of intervals that are smaller than months, perhaps weeks. In (10) it will consist of intervals whose length is one or two levels lower than the length *half an hour* with respect to a pragmatic granularity hierarchy of temporal length units. The repetition in (10), then, might follow a five minute rhythm.

Of course, the iterative analysis of examples like (9) and (10) can be expressed in DRT also by universal quantification over the intervals of the grid via a duplex condition, instead of applying the operator *ITER* to the basic event predicate. We will prefer this representation style for iteration readings throughout the rest of this paper. [15]

It is often not clear whether the entities introduced by descriptions that use plural phrases for characterizing thematic roles (as in the following example (11)), or that require iteration, are conceptualized as single events or as event sums.

(11) *Peter trank fünf Gläser Bier.*
(Peter drank five glasses of beer.) [16]

Does example (11) introduce one single event of *Peter drinking five glasses of beer* or does it introduce five events of *Peter drinking a glass of beer* (or the corresponding sum respectively)? And does (10) introduce one repetitive event of *the stuntman throwing himself out of the window* or does it introduce an unknown number of *the stuntman throwing himself out of the window*-events (or the corresponding non-atomic sum respectively)? In order to deal correctly with this underdetermination, i.e. in order to treat both cases, in (IV) we have only required that the homogeneous P has to be materially equivalent to some $ITER(Q)$ instead of requiring $P = ITER(Q)$.

Of course, event predicates $P1, P2$ are materially equivalent iff for each element of $P1$ there exists a materially equivalent element of $P2$ and vice versa. We note, that, in accordance with this, (I)-(III) can also deal with this ontological underspecification.

One may suspect that the use of material equivalence in (IV) causes the test described by (I)-(III) to be superfluous, since (IV), with seemingly weaker conditions, besides sum predicates, can test predicates over single events by this means. We stress that one cannot dispense with (I)-(III). Defining homogeneity in terms of iteration ($P =_m ITER(Q)$), in order to deal correctly with threshoulds, requires that the defined predicate, P, and the underlying defining predicate, Q, must be materially different. $P =_m ITER(P)$ means, that each instance of P can be infinitely divided into P-instances. For Ps like *Paola working in the garden* this, obviously, is false. However, $P =_m ITER(P)$ seems to be the only possibility of an iterative description of such Ps.

Summarizing we give the following formal characterization of homogeneity.

Definition: Temporal Discourse-Homogeneity

Let P be an event predicate:

$$
\begin{aligned}
& TD-HOM(P) \\
& \leftrightarrow \\
& ([\exists e, e' \ (P(e) \wedge P(e') \wedge e \circ_m^{max} e' \wedge \neg(e \leq_m e' \vee e' \leq_m e)) && \text{(a)} \\
& \quad \wedge \\
& \quad \forall e, e' \ (P(e) \wedge P(e') \wedge e \circ_m^{max} e' \rightarrow \exists e" \ (e \sqcup_i e' =_m e" \wedge P(e"))) && \text{(b)} \\
& \quad \wedge \\
& \quad \forall e, t, \bar{e} \ (P(e) \wedge interval(t) \wedge t \subseteq lz(e) \wedge \textit{max-t-auss}(\bar{e}, t, e) \wedge size(\bar{e}) \geq limit(P) \\
& \qquad\qquad \rightarrow \exists e' \ (e' =_m \bar{e} \wedge P(e'))] && \text{(c)} \\
& \vee \\
& \exists Q \ (P =_m ITER(Q))) && \text{(d)}
\end{aligned}
$$

Here, of course, (a), (b), (c) in turn reflect (III), (II), (I). (d) reflects (IV). We call a predicate P satisfying (a)-(c) on the one hand or (d) on the other **t***emporally* **d***iscourse*-**hom***ogeneous*, *TD-HOM(P)*. We call such a predicate P not simply 'temporally homogeneous', or 'homogeneous', in order to point to the fact that P is not necessarily cumulative or distributive with respect to the rigid meaning of these notions, but is cumulative and distributive only with respect to the discourse oriented, pragmatically determined, temporal use of these notions. The usefullness of the presented weak, but interdependent versions of cumulativity and divisivity is confirmed, as we think, by the examples considered this far in this section.

Now we can easily define heterogeneity as the counterpart of homogeneity.

Definition: Temporal Discourse-Heterogeneity

Let P be an event predicate:

$TD - HET(P) \leftrightarrow \neg TD - HOM(P)$

The formal means developed until now allow to represent the critical examples (4a) - (4d), according to the analysis sketched in the introduction.

(4) a. *Sportler brachten die olympische Fackel nach Barcelona.*
(Sportsmen took the olympic torch to Barcelona.)

($4a_{rep}$)

U, v, e, barcelona
sportsman*(U) o-torch(v) take(e) agent(e)=U object(e)=v goal(e)=barcelona

(4) b. *Olympia-Fans fuhren nach Barcelona.*
(Olympics fans went to Barcelona.)

($4b_{rep}$)

U, E1, barcelona
o-fan*(U) E1 :: [u | $u \in_i U$] ⟨every u⟩ [e1 | $e1 \in_i E1$, go(e1), theme(e1) = u, goal(e1) = barcelona] temp-distr(E1)

(4) c. *Beim Stürmer-Training drosch Völler Bälle ins Tor.*
(At the forward training, Völler kicked balls into the goal.)

($4c_{rep}$)

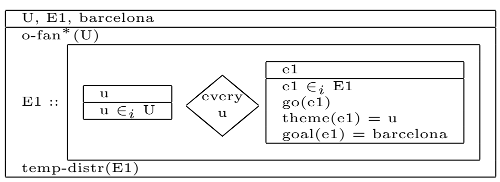
e, U, v, E1, völler
forward-training(e) ball*(U) goal(v) E1 :: [u | $u \in_i U$] ⟨every u⟩ [e1 | $e1 \in_i E1$, kick(e1), agent(e1) = völler, goal(e1) = v, e1 ⊘ e] temp-distr(E1)

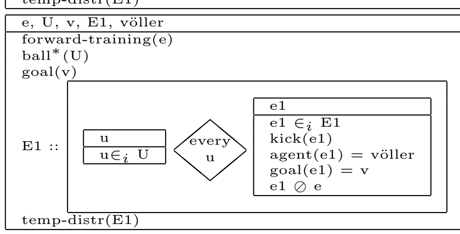
(4) d. *Am Mittwoch transportierte ein FIFA-Mitarbeiter Bälle von London nach Rom.*
(On Wednesday, a FIFA-employee carried balls from London to Rome.)

($4d_{rep}$)

t, u, V, e, london, rome
wednesday(t) FIFA-employee(u) ball*(V) transport(e) theme(e)=u object(e)=V source(e)=london goal(e)=rome e ⊆ t

In the theoretical framework that we have developed the readings ($4b_{rep}$) and ($4c_{rep}$) of (4b), and of (4c) respectively, are homogeneous event descriptions, because the corresponding event predicates, $P1$ and $P2$, are predicates satisfying the (d)-condition of the *TD-HOM*-definition. $P1$ and $P2$ can be represented as follows:

$P1 = \lambda$ E1 

$P2 = \lambda$ E1 

$P1$ and $P2$ satisfy (d), since they are iterations (in the sense of *ITER*) of $Q1$ and $Q2$ respectively, with:

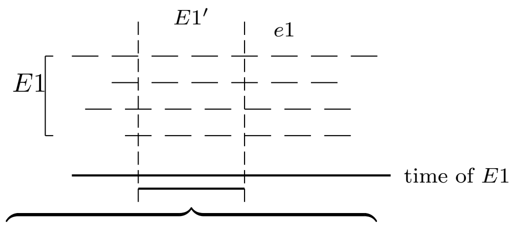
$Q1 = \lambda$ e1

u, e1
o-fan(u) go(e1) theme(e1) = u goal(e1) = barcelona

and $Q2 = \lambda$ e1

e1, u
forward-training(e) ball(u) goal(v) kick(e1) agent(e1) = völler goal(e1) = v e1 ⊘ e

Note that in $Q2$ the DRFs e and v behave like the DRT-constants *barcelona* and *völler*, because they are free variables. With respect to a specific assignment function $\hat{f}$, independently on the interpretation of the DRFs $e1$ and u via extensions of $\hat{f}$, they always denote the same object in the model ($\hat{f}(e)$ and $\hat{f}(v)$ respectively). [17] This possibility for making use of event types, that, so to speak, are *parameterized*, guarantees that defined predicates like $P2$ have indeed an iterative characterization. Without this formal means of free variables we could not make sure that the *forward-training* in $Q2$, and the *goal* respectively, must always be the same. Clearly, with respect to the event type $Q2'$ that develops from $Q2$ by introducing e and v in the universe of the $Q2$-DRS, the extension of $P2$ is a strict subset of the set of iterations of $Q2'$-elements, provided the interpreting model contains several forward trainings and several goals. Thus, the parameterization is indeed needed for the characterization of the $P2$-elements as iterations of events of some other event type. [18] We can graphically render the particular characteristics of (4b) and (4c) as follows:



time of a subsum $E1'$ of $E1$ which respects the grid granularity of $E1$

$E1$ consists of an unspecified number of temporally homogeneously distributed atomic events $e1$, each satisfying the same event predicate($Q1$, or $Q2$ respectively). Because the number of these events is not prescribed by the characterization $P1$ of $E1$, (or by $P2$ respectively), subsums $E1'$ of $E1$ that are distributed over subgrids of the grid of $E1$ can be characterized by the same event type, i.e. by $P1$, (or by $P2$ respectively). This reflects the divisivity of $P1$ and $P2$. Adding $P1$-sums ($P2$-sums) $E2'$ to $E1'$ that share a common $Q1$-event ($Q2$-event) with $E1'$, obviously returns sums $E1' \sqcup_i E2'$ that are $P1$-sums ($P2$-sums). This reflects the cumulativity of $P1$ and $P2$.

We stress that, in contrast to examples like (9), (*Peter eating a trotter for months*), we do not need *type coercion* in order to obtain the homogeneous representations of (4b) and (4c). [19] Analyzing the (simplified) (9), first we obtain the event type

R=λ e [u, e | trotter(u), eat(e), agent(e) = peter, object(e) = u],

which is not homogeneous. Since *for months* expects a homogeneous event type, R must undergo a type coercion. Here, this will be effected via iteration. We obtain:

$R' = ITER($ λ e [u, e | trotter(u), eat(e), agent(e) = peter, object(e) = u]), or, spelling out the impact of *ITER*:

R' = λ E [E, T | grid(T), E :: [[t | t $\in_i$ T] ⟨every t⟩ [u, e | e $\in_i$ E, trotter(u), eat(e), agent(e) = peter, object(e) = u, e ⊘ t]]] 20

Instead of creating another event type with disjoint extension (via iteration), in the case of (4b) and (4c), we have only to strengthen the explicitly given event type by the *temp-distr*-condition.

We have said nothing yet about the condition $e1 \in_i E1$ in the nuclear scope of the duplex condition of $P1$ (and of $P2$ respectively, compare also $e \in_i E$ in R'). Without this condition, the abstraction condition $E1 :: \ldots$ in $P1$ would determine $E1$ to be the maximal sum of $Q1$-events that are related to the u's of U via *theme*. This means that, for each u of U, $E1$ would comprise all the journeys to Barcelona undertaken by u. Clearly, (4b) only refers to a sum $E1$ that accounts for at least one travelling event with respect to each u of the introduced sum of Olympics fans. This sum $E1$ does not necessarily account for all such travelling events. We easily verify that restricting the abstraction condition $E1 :: \ldots$ by the incorporated condition $e1 \in_i E1$ blocks the inference that $E1$ must be the maximal sum of journeys to Barcelona undertaken by the u's of U. But we stress that this restriction does not alter the property of $E1$ of exhausting the sum U in the sense of providing a travelling to Barcelona for each of the u's of U. This is easily verified too. Of course, the corresponding statement holds for $P2$, and for all the other event types that use the formal means of abstracting event sums from duplex conditions.

($4a_{rep}$) and ($4d_{rep}$) represent heterogeneous event descriptions. However, whereas the theory that we have outlined, in the case of ($4b_{rep}$) and ($4c_{rep}$), really **entails** the Aktionsart, with ($4a_{rep}$) and ($4d_{rep}$), as with the examples of (8), there exists no comparable formal decision yet. It is the knowledge of the language user about the canonical realization of the described event types that requires that the types of (8a)-(8d) satisfy to TD-HOM and that the types of (8e)-(8h), ($4a_{rep}$) and ($4d_{rep}$) do not. In order to constrain the theory in this respect, we can introduce a number of axioms of the type TD-HOM(P) and TD-HET(P) respectively that structure the extensions of the corresponding Ps in interpreting models as desired. We abstain from this, since this modelling would not sufficiently reflect the *compositional nature* of Aktionsarten[21] that we observe not only with regard to quantificational phenomena, but already in the presence of single event descriptions.

Making use of specific role properties like *additivity*, where a (functional) role f is additive iff

$$\forall e, e' \quad (f(e) \sqcup f(e') = f(e \sqcup e'))$$

Krifka explains very convincingly for cases like (7a) and (7b) (*Peter drinking wine* versus *Peter drinking a glass of wine*) how the specific description of thematic roles adds to the basic predicate stemming from the verb and, therefore, how it influences the quality of the entire event description in terms of the structural properties of the corresponding extension in the model. The reasoning that explicates the different Aktionsarten of (7a) and (7b) can be sketched as follows: *wine* is cumulative, because the fusion of two portions of wine is also a portion of wine. In contrast, *one glass of wine* is not cumulative, because the fusion of two glasses of wine is not *one glass of wine*; *drinking* as such is cumulative: two activities of drinking taken together form one (perhaps more complex) drinking activity. Thus, for $e_1, e_2 \in \lambda e(drink(e) \wedge \exists x(wine(x) \wedge object(e) = x))$, we get that $drink(e_1 \sqcup e_2)$ and $wine(object(e_1) \sqcup object(e_2))$ hold. Since *object* is additive, we get from the latter statement that $wine(object(e_1 \sqcup e_2))$ holds. Therefore, it holds that $e_1 \sqcup e_2 \in \lambda e(drink(e) \wedge \exists x(wine(x) \wedge object(e) = x))$. We easily see that for $P = \lambda e(drink(e) \wedge \exists x(\textit{1-glass-wine}(x) \wedge object(e) = x))$ and $P(e_1), P(e_2)$, it does not hold $P(e_1 \sqcup e_2)$.

Besides the (canonical) adaptation of *additivity* to our structuring using $\sqcup_i, \leq_i, \leq_m$ - we call it *summativity*, the essential properties are the following:

Let P be a predicate symbol that describes single events. Then:

• f is a *constant* role with respect to P, const(f,P)
iff

$$\forall e, e', x \ (P(e) \wedge f(e) = x \wedge atom(x) \wedge P(e') \wedge \textit{max-t-auss}(e', temp(e'), e) \rightarrow f(e') =_m x)$$

• f is a *gradual* role with respect to P, grad(f,P)
iff

$$\forall e, x, x' \ (P(e) \wedge f(e) = x \wedge atom(x) \wedge x' <_m x \rightarrow \exists e' \ (P(e') \wedge \textit{max-t-auss}(e', temp(e'), e) \wedge f(e') =_m x'))$$

• f is a *characteristic* role with respect to P, char(f,P)
iff

$$\neg grad(f, P) \wedge (const(f, P) \rightarrow (\forall e, e', t(P(e) \wedge P(e') \wedge \textit{max-t-auss}(e', t, e) \rightarrow e' =_m e)))$$

Thus, we say that f is a *constant* role with respect to the predicate P, if the maximal P-segments of a P-event e share the f-value with e. Here, we refer to events e with atomic values only, in order to avoid complications with single event conceptualizations of sums that develop from distributions over plural roles. An example of a constant role is the *theme*-role of moving-events. Maximal segments e' of a moving of x that are moving-events are movings of x. In contrast to this, maximal segments of an *eating* x-event that are also eating-events have values of the *object*-role that are material parts of x. We call a role f *gradual* with respect to the predicate P if from the existence of a P-event e with atomic f-value x, we can infer the existence of maximal P-segments e' of e such that for each part x' of x there is a e' whose f-value is materially equivalent to x'. The *object*-role with respect to consumption predicates like *eating* is a gradual role. We call a role f *characteristic* with respect to the predicate P if f is not gradual with respect to P and if f, in case it is constant, for lack of a rich homogeneous structuring of the P-extension, it is only trivially constant. *Source* and *goal*, for instance, are characteristic with respect to *moving*-events. From a moving to x we cannot infer that all maximal *moving*-segments are movings to x. Nor can we infer the existence of movings to parts to x. Segments of moving events e normally have completely different sources and goals than e.

We can use such role properties in order to compute the Aktionsart of event descriptions that equip the roles with atomic values. The basis is the Aktionsart of the underlying simple event predicate. Of course, the assignment of Aktionsarten to predicate symbols has to be axiomatically given in order that the calculus is sound with respect to interpreting models of the theory. Similarly, the role properties that the calculus uses will be anchored in corresponding axioms of the theory. Constant roles do not change the Aktionsart. Characteristic and gradual roles transpose homogeneous descriptions into heterogeneous descriptions. This can be easily verified. *Going*s and *reading*s are homogeneous, *going of peter*- and *reading by peter*-descriptions too, but *going of peter to France*- and *reading a book by peter*-descriptions are heterogeneous. We will not go into detail with this type of Aktionsart computation. We also skip presenting the precise theoretical settings for mass terms and measure phrases that allow to infer the correct Aktionsarten for the examples that are relevant in this respect, i.e. (7a), (8f) and (8g). We stress however that the role properties must be relativized to the specific predicates, provided that we use identical roles for different predicates. *Object* is gradual with respect to *eating*-, but not with respect to *transporting*-events. There is even a finer distinction. For particular predicates there are roles that can have both a gradual and a constant reading. Paola's *caressing a dog* in (8c) can be a caressing of a level of granularity that does not pay attention to the parts of the dog. With respect to each maximal caressing-segment the dog as a whole is involved. The *object*-role is constant then, but it can also be gradual: Think of the caressing as a task that starts with the caressing of the head and ends with the caressing of the paws. In order to capture the difference, we can introduce a more fine-grained spectrum of roles where the roles can have indices *suk* and *sim* that point to the gradual variant, where the partaking role value is *successively* involved in the event, and to the constant variant, where it is always involved as a whole, i.e. where its parts are involved *simultaneously*. So, in the above discussion about the definition of homogeneity, precisely speaking, we can attribute homogeneous Aktionsart to (8c) only if we refine the *object*-role to $object_{sim}$. The introduction of these indices is inspired by the two-place relations *SUK* and *SIM* that Krifka suggests for plural examples like Paola's caressing of two cats in (8d). As mentioned, Krifka's Aktionsart analysis does not make use of *distributive* readings of plural roles as in ($4b_{rep}$) with respect to the *Olympics-Fans* (travelling to Barcelona) or in ($4c_{rep}$) (the *balls* kicked into the goal). Only *collective* readings are considered, as in ($4a_{rep}$) (the *sportsmen* carrying the olympic torch to Barcelona), or in ($4d_{rep}$) (the *balls* carried to Rome). The suggested Aktionsart analysis completely relies on the transfer of the type of referentiality of the roles to the event description. This transfer proceeds along the lines of role properties like additivity, as discussed with respect to the contrast between (7a) and (7b). The introduction of the roles *SUK* and *SIM* allows to correctly distinguish between the homogeneous and the heterogeneous reading of cases like *Paola caressing two cats* (with *two cats* as filler of *SIM* and of *SUK* respectively).

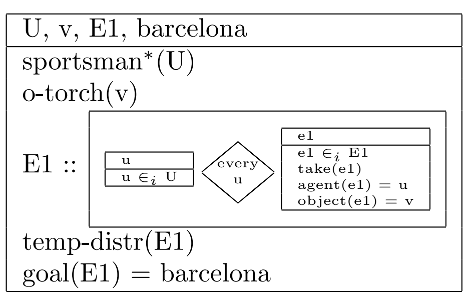
The problem with an approach that uses exclusively single events is that, for divisivity based notion of homogeneity, we obtain the right result for cases like (4b) (Olympics fans travelling to Barcelona), namely homogeneity (in the sense of point (d) of the TD-HOM-definition, case 'type of single events'), only if the *theme*-role is interpreted as *SUK*, and only if the *goal*-role has the property that event segments corresponding to the successively partaking constituents of the plural role, the Olympics fans in (4b), inherit the value of the *goal* of the entire event. But uniformly requiring this property for *goal* with respect to single moving-events would result in the impossibility of representing the 'Olympics' case of (4a) by a single event, since, under the assumption of this property, each of the sportsmen must run to Barcelona. Of course, this does not truly reflect the 'Olympics' case, where the sportsmen act *successively*, each running a particular section of the way to Barcelona with the torch in hand and handing it to the next sportsman. Actually, only the last of the sportsmen reaches Barcelona with the torch in hand.

Thus, we think that a distributive analysis of cases like (4b) is needed. We render the contrast between simultaneously partaking constituents of a plural role (*SIM*) and successively partaking constituents (*SUK*) by the *temp-sim/temp-distr*-distinction for distributive readings, where *temp-sim* is defined as follows:

- for all event sums E, it holds *temp-sim(E)* iff $\forall e, e' \in_i E(temp(e) = temp(e'))$.

The *suk/sim*-indices are reserved to mark the grad- and const-specification of a role that otherwise would be underspecified in this respect. The assumption is that the lexicon entries provide roles that are specific with respect to the relevant role properties. We stress that with this setting the collective reading of sum values of constant roles is restricted to the case of simultaneity, the collective reading of sum values of gradual roles is not successivity with respect to the partaking atoms, but not further specified gradual affectedness of the sum. The examples that refer to sums whose atoms are successively involved in the event will be represented exclusively by distribution. Thus, we have to correct our analysis of (4a). We represent (4a) as follows:

(4a$_{rep}$')



We summarize the essential points of this section. The definition of homogeneity is based on cumulativity and divisivity. It is sensitive to changes of granularity as connected to the transition from non-iterative to iterative event types. It is applicable to types of single events and to types of event sums. The assumption is that there is a set of axioms that determines the Aktionsart of the predicate symbols of the fragment and that there is a set of axioms that, dependent on the specific event predicates, determines the relevant properties of the roles that are used. Here, roles can be summative, constant, gradual or characteristic. From these facts the Aktionsart of event predicates with atomic role values easily can be inferred, if these values are described by count noun-expressions, and, provided a rich axiomatic modelling, also if they are described by mass- and measure-expressions. We skip formally working out this type of Aktionsart calculus and, in the next section, assume lexicon entries of the verbs that already account for the Aktionsart-influence of the roles introduced by the subcategorized grammatical functions. This lexical account is restricted to the assumption that the roles come with atomic values that are described by predicates that stem from count nouns. The task will be to concentrate on the impact on the Aktionsart in cases where the lexical expectation of atomic role values is contradicted by plural phrases.

4. Partial DRSs for Distributive and Collective Readings

We develop our DRS-construction algorithm in a Categorial Unification Grammar-like framework, concentrating on the semantic part of the lexical entries and skipping the syntactic part where possible. The relevant parts of the lexical entries for verbs look like follows:

- lesen

$\longrightarrow$

$$< e_{[\ akt:hom\ ]}, \begin{array}{|l|}\hline \text{e} \\ \hline \text{read(e)} \\ \text{agent(e) = x} \\ \hline \end{array}_{[x_{\left[\begin{array}{l} case:nom \\ rp:const \end{array}\right]}]} >$$

for *s.o. reads.*

- lesen

$\longrightarrow$

$$< e_{[\ akt:het\ ]}, \begin{array}{|l|}\hline \text{e} \\ \hline \text{read(e)} \\ \text{agent(e) = x} \\ \text{object(e) = y} \\ \hline \end{array}_{[x_{\left[\begin{array}{l} case:nom \\ rp:const \end{array}\right]}, y_{\left[\begin{array}{l} case:acc \\ rp:grad \end{array}\right]}]} >$$

for *s.o. reads s.th.*.

- lieben

$\longrightarrow$

$$< e_{[\ akt:hom\ ]}, \begin{array}{|l|}\hline \text{e} \\ \hline \text{love(e)} \\ \text{theme(e) = x} \\ \hline \end{array}_{[x_{\left[\begin{array}{l} case:nom \\ rp:const \end{array}\right]}]} >$$

for *s.o. is in love.*

• lieben

$\longrightarrow \quad < e_{[\ akt:hom\ ]}, \begin{array}{|l|}\hline \text{e} \\ \hline \text{love(e)} \\ \text{theme(e) = x} \\ \text{object(e) = y} \\ \hline \end{array}_{[x_{\left[\begin{smallmatrix} case:nom \\ rp:const \end{smallmatrix}\right]}, y_{\left[\begin{smallmatrix} case:acc \\ rp:const \end{smallmatrix}\right]}]} >$

for *s.o. loves a p.*.

Here, German verbs are listed that may or may not occur with direct objects in grammatically correct German sentences. In order to account for this syntactic behavior, we require two lexical entries for *lesen* and *lieben* respectively. The one reflects the case where the verb syntactically is a functor of the type S/NP$_{nom}$, the other reflects the case where it is a functor of the type S/NP$_{nom}$/NP$_{acc}$. The assignment of values to the feature *akt* (Aktionsart) in the lexicon is based on the assumption that the DRFs stemming from the subcategorized grammatical functions are atomic objects (introduced by singular NPs using count nouns: *ein Mann, ein Hund, ein Buch*, (*a man, a dog, a book*). Depending on the specific contribution of the thematic roles introduced, the Aktionsart of the event type of the S/NP$_{nom}$/NP$_{acc}$-entry may be different from the Aktionsart of the event type of the S/NP$_{nom}$-entry. Adding gradual or characteristic roles with atomic values to homogeneous event types results in heterogeneous event types. In contrast, constant roles with atomic values do not change the Aktionsart. This was mentioned in the previous section. The entries are to be read as follows: The verb introduces a DRS with free variables. These free variables must be bound via lambda conversion by the DRFs introduced by the syntactic arguments of the verb functor. The arguments are the items of the subcategorization list. With respect to the second entry of *lesen* for instance, $[x_{case:nom}, y_{case:acc}]$ is the sketchy representation of the subcategorization list which tells us that *lesen* is a functor with arguments of the type nominal NP and of the type accusative NP, and that applying the functor to the nominal argument results among other things in replacing x by the DRF of the nominal NP and accordingly in the case of the accusative NP. We note that DRSs come with an *index* (i.e. with a DRF directly preceding the DRS). With VPs, it is the event introduced in the universe of the corresponding DRS. With NPs, normally, it is the DRF introduced by the head noun. We use indices because they ease the construction of the semantic representation that parallels the syntactic analysis via functional application (and composition). For instance, in the case of NPs with relative clauses several DRFs are introduced. Here, the index decides which one must be chosen for binding the corresponding variable of the VP representation. [22] The index and the DRFs of the subcategorization list are annotated by the relevant syntactic and semantic features that describe the structure introducing the corresponding DRF. Thus, $[akt : hom]$ in $< e_{[akt:hom]}, DRS >$ means that $\lambda e DRS$ is a homogeneous event predicate. We note, by the way, that role properties like being a constant role etc. are not part of the information stemming from the corresponding NPs, but are assigned to these NPs by the verb via the subcategorization list and especially via the feature *rp*. Of course, such information represents the axiomatic knowledge mentioned in the last section. Thus, using lexical entries dynamically builds up the data base of our DRT-theory that underlies the evaluation of the constructed DRSs. With respect to nominal phrases, we concentrate on the semantic contribution of indefinite singular and plural noun phrases. In this paper we will say nothing specific about NPs with quantifiers like *many, few, most* etc. However, one easily sees that in the presence of the TD-HOM-definiton, such NPs will be treated like indefinite numeral NPs, as far as Aktionsart is concerned. We will say something about definite NPs only in the next section. We omit the construction of the NP representations from the representations of determiners and nouns and render only the schemes of the representations of entire NPs like *a man, three men, men* accounting for the distinction of collective, *temp-sim*- and *temp-distr*-distributive readings that we label in turn by C, D_{tsim} and D_{tdistr}. In the following schemes we abstract from case information. In specific representations this information would be available by means of the case attribute connected to the DRF that the NP determines as the filler of the thematic role corresponding to the NP.

- $\boxed{\text{ein cn}}$, where $cn \in NOUN_{\left[\begin{smallmatrix} num=sg \\ type=count \end{smallmatrix}\right]}$

$\longrightarrow$

$$(C) \qquad < \mathrm{x}, \lambda < \varepsilon_{[akt:A]}, \mathrm{DRS}_{[\ldots \mathrm{x} \ldots]} > \left[< \varepsilon_{[akt:A]}, \mathrm{DRS} \cup \begin{array}{|c|}\hline \mathrm{x} \\ \hline \mathrm{cn'(x)} \\ \hline \end{array} [\ldots] > \right] >$$

- $\boxed{\text{n cn}}$, where $n \in DET_{\left[\begin{smallmatrix} num=pl \\ quant=ind \end{smallmatrix}\right]}, n \neq \emptyset, cn \in NOUN_{\left[\begin{smallmatrix} num=pl \\ type=count \end{smallmatrix}\right]}$

$\longrightarrow$

$$(C) \qquad < \mathrm{X}, \lambda < \varepsilon_{[akt:A]}, \mathrm{DRS}_{[\ldots \mathrm{X} \ldots]} > \left[< \varepsilon_{[akt:A]}, \mathrm{DRS} \cup \begin{array}{|l|}\hline \mathrm{X} \\ \hline \mathrm{cn'^*(X)} \\ |\mathrm{X}| = \mathrm{n} \\ \\ \hline \end{array} [\ldots] > \right] >$$

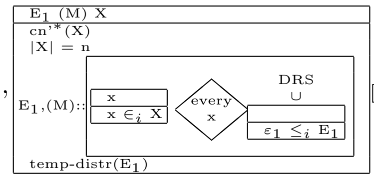
$\longrightarrow$

$$(D_{tsim})$$

$$< \mathrm{x}, \lambda < \varepsilon_{1[akt:A]}, \mathrm{DRS}_{[\ldots \mathrm{x} \ldots]} > \left[< \mathrm{E}_{1[akt:A]}, \begin{array}{|l|}\hline \mathrm{E_1 \ (M) \ X} \\ \hline \mathrm{cn'^*(X)} \\ |\mathrm{X}| = \mathrm{n} \\ \mathrm{E_1,(M)::} \begin{array}{|c|}\hline \begin{array}{|c|}\hline \mathrm{x} \\ \hline \mathrm{x} \in_i \mathrm{X} \\ \hline \end{array} \ \Big\langle \begin{matrix}\text{every} \\ \mathrm{x}\end{matrix} \Big\rangle \ \begin{matrix} \mathrm{DRS} \\ \cup \\ \begin{array}{|c|}\hline \\ \hline \varepsilon_1 \leq_i \mathrm{E_1} \\ \hline \end{array} \end{matrix} \\ \hline \end{array} \\ \text{temp-sim}(\mathrm{E_1}) \\ \hline \end{array} [\ldots] > \right] >$$

$\longrightarrow$

(D_{tdistr})

$<\!x, \lambda <\!\varepsilon_{1[akt:A]}, \mathrm{DRS}_{[\ldots x \ldots]}\!> \Big[<\!E_{1[akt:het]},$  $[\ldots]\!> \Big] >$

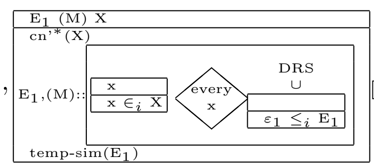
• $\boxed{\emptyset \text{ cn}}$, where $cn \in NOUN_{\left[\begin{smallmatrix} num=pl \\ type=count \end{smallmatrix}\right]}$

$\longrightarrow$

(C) $\quad < X, \lambda < \varepsilon_{[akt:A]}, \mathrm{DRS}_{[\ldots X \ldots]} > \Big[< \varepsilon_{[akt:A]}, \mathrm{DRS} \cup \boxed{\begin{array}{c} X \\ \hline cn'^*(X) \end{array}} [\ldots] > \Big] >$

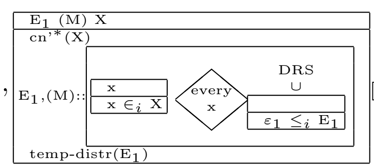
$\longrightarrow$

(D_{tsim})

$<\!x, \lambda <\!\varepsilon_{1[akt:A]}, \mathrm{DRS}_{[\ldots x \ldots]}\!> \Big[<\!E_{1[akt:A]},$  $[\ldots]\!> \Big] >$

$\longrightarrow$

(D_{tdistr})

$<\!x, \lambda <\!\varepsilon_{1[akt:A]}, \mathrm{DRS}_{[\ldots x \ldots]}\!> \Big[<\!E_{1[akt:hom]},$  $[\ldots]\!> \Big] >$

The formal description of the NP classes considered should be rather self-explanatory. We represent the cases treated, NPs constructed from the empty determiner or numerals on the one hand and singular or plural count nouns on the other, (and other NPs) by annotated *partial DRSs* that are equipped with indices. Disregarding the annotations, a partial DRS syntactically is a function from DRSs onto DRSs (representing a function from propositions onto propositions). [23] We see that, with respect to the semantic representation, the roles played syntactically by NP and VP are exchanged with each other. Applying the VP-functor to the nominal argument by means of the grammar rules results in applying the semantic representation of the NP, the semantic functor, to the semantic representation of the VP, the semantic argument. [24] Instead of explaining the representation schemes listed, we render constructions of the semantic representations for our examples (4a) and (4d). Therefore, in addition, we need representations of prepositional phrases. Here, we restrict ourselves to the illustrative examples *nach Rom* and *mit Maria*. The first example reflects the case of VP- (or sentence-) modification via a characteristic role (which, here, is *goal*), the second reflects the case of modification via a constant role (which, here, is *commitative*). With respect to our examples (4a) - (4d), the second PP is not needed. We provide its representation only to illustrate that there are PPs that influence the Aktionsart of the sentence differently from source or goal descriptions. We do not give the details of the construction of PPs from prepositions and noun phrases (which, here, are names).

- nach Rom

$$\longrightarrow \quad < \text{rome}, \lambda < \varepsilon_{[akt:A]}, \text{DRS}_L > \left[< \varepsilon_{[akt:het]}, \text{DRS} \cup \begin{array}{|c|}\hline \text{rome} \\ \hline \text{goal}(\varepsilon)=\text{rome} \\ \hline \end{array}_L > \right] >$$

- mit Maria

$$\longrightarrow \quad < \text{maria}, \lambda < \varepsilon_{[akt:A]}, \text{DRS}_L > \left[< \varepsilon_{[akt:A]}, \text{DRS} \cup \begin{array}{|c|}\hline \text{maria} \\ \hline \text{commitative}(\varepsilon)=\text{maria} \\ \hline \end{array}_L > \right] >$$

In order to construct the reading ($4a_{rep}$') of (4a), we must make use of the D_{tdistr}-reading of *sportsmen*. Postponing the representation of definite NPs we treat **die** *olympische Fackel* like the corresponding indefinite *eine Fackel*. So the components of ($4a_{rep}$') are:

($4a_{rep}$')$_V$:

$$< e_{1[akt:hom]}, \begin{array}{|l|}\hline e_1 \\ \hline \text{carry}(e_1) \\ \text{agent}(e_1) = x \\ \text{object}(e_1) = y \\ \hline \end{array}_{[x_{\left[\substack{case:nom \\ rp:const}\right]}, y_{\left[\substack{case:acc \\ rp:const}\right]}]} >$$

($4a_{rep}$')$_{NP_{nom}}$:

$$<u, \lambda < \varepsilon_{1[akt:A]}, \text{DRS}_{[\ldots u_{[case:nom]}\ldots]}> \left[< E_{1[akt:hom]}, \begin{array}{|l|}\hline E_1 \ (M) \ U \\ \hline \text{sportsman}^*(U) \\ E_1,(M) :: \begin{array}{|c|}\hline \begin{array}{|c|}\hline u \\ \hline u \in_i U \\ \hline \end{array} \ \langle \substack{\text{every} \\ u} \rangle \ \begin{array}{c} \text{DRS} \\ \cup \\ \begin{array}{|c|}\hline \\ \hline \varepsilon_1 \leq_i E_1 \\ \hline \end{array} \end{array} \\ \hline \end{array} \\ \text{temp-distr}(E_1) \\ \hline \end{array}_{[\ldots]} > \right] >$$

($4a_{rep}$')$_{NP_{acc}}$:

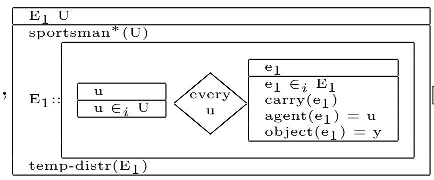
$$< v, \lambda < \varepsilon_{[akt:A]}, \text{DRS}_{[\ldots v_{[case:acc]}\ldots]} > \left[< \varepsilon_{[akt:A]}, \text{DRS} \cup \begin{array}{|c|}\hline v \\ \hline \text{o-torch}(v) \\ \hline \end{array}_{[\ldots]} > \right] >$$

($4a_{rep}$')$_{PP_{goal}}$:

$$< \text{barcelona}, \lambda < \varepsilon_{[akt:A]}, \text{DRS}_L > \left[< \varepsilon_{[akt:het]}, \text{DRS} \cup \begin{array}{|c|}\hline \text{barcelona} \\ \hline \text{goal}(\varepsilon)=\text{barcelona} \\ \hline \end{array}_L > \right] >$$

Now, we first apply the verb to the nominative NP, i.e., semantically we apply the representation of the nominative NP, ($4a_{rep}$')$_{NP_{nom}}$, to the representation of the verb, $(4a_{rep}')_V$. This means that the verb representation is unified with the indexed and annotated DRS-variable that the lambda abstraction of $(4a_{rep}')_{NP_{nom}}$ refers to, $(< \varepsilon_{1[akt:A]}, DRS_{[\ldots u_{[case:nom]} \ldots]} >)$. Here, the case information guarantees that x unifies with u and that u is indeed the filler of the agent role. Also ε_1 unifies with e_1 and A with *hom*. The result of the application is the bracketed indexed and annotated DRS to the right of the NP representation after unification. So, from applying the verb to the nominative NP, the following representation results:

$(4a_{rep}')_{NP_{nom},V}$: $< E_{1[akt:hom]}$,

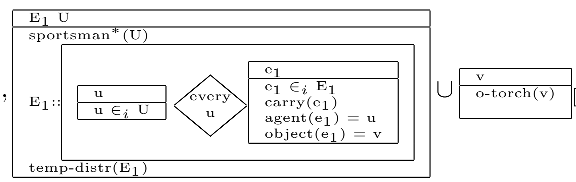


$[y_{[case:acc]}] >$

Note that the [*case: nom*]-item is removed from the subcategorization list according to the sketchy transition from $[\ldots x \ldots]$ to $[\ldots, \ldots]$ that we have used in the NP-representation schemes. Notice further that the application of the D_{tdistr}-reading of bare plural NPs always results in homogeneous event descriptions. The next step consists of applying the representation of the accusative NP, $(4a_{rep}')_{NP_{acc}}$ to what we have constructed so far. Here, unifying y with v, ε with E_1, A with *hom*, DRS with the DRS of $(4a_{rep}')_{NP_{nom},V}$, we obtain:

$(4a_{rep}')_{NP_{acc},NP_{nom},V}$:

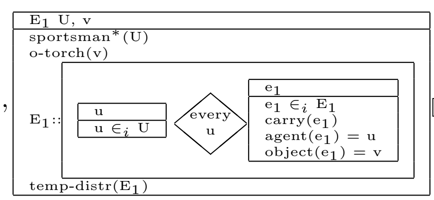
$< E_{1[akt:hom]}$,



$[] >$

This is equivalent to:

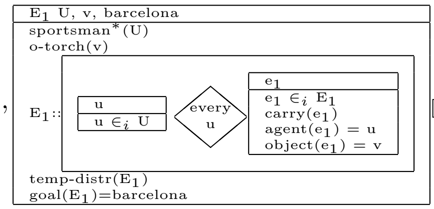
$(4a_{rep}')_{NP_{acc},NP_{nom},V}$: $< E_{1[akt:hom]}$,



$[] >$

Here, we notice that indefinite singular NPs do not change the Aktionsart of the incoming event description. They confirm the expectation underlying the lexical entry of the verb. It is easy to show that, on the basis of our definitions of homogeneity and heterogeneity and with respect to these notions, the collective and the *tsim*-distribution reading of (subcategorized) plural NPs behave in accordance with this. In the final step we apply $(4a_{rep}')_{PP_{goal}}$ to $(4a_{rep}')_{NP_{acc},NP_{nom},V}$. This yields:

$(4a_{rep}\text{'})_{PP_{goal},NP_{acc},NP_{nom},V}$:

$< \mathrm{E}_{1[akt:het]},$  $[\,] >$

Here, we have skipped the step of carrying out the union of incoming DRS and role-DRS that we have made explicit in the preceding application step. We see that PPs leave the subcategorization list unchanged. Since in $(4a_{rep}\text{'})_{PP_{goal},NP_{acc},NP_{nom},V}$, this list is empty, we can remove it without consequences. The result is the indexed ($4a_{rep}$') with the Aktionsart *het(erogenous)* annotated. Of course, we obtain *het*, since subevents do not (necessarily) inherit the *goal* of the entire event. This is different with respect to constant PP-roles like *commitative* or *instrument*. In order to keep track of the construction steps of a sentence reading, we introduce list-expressions where the items describe the role-readings using the labels of the representation schemes and the role name, and where the order of the list items reflects the order of the application steps. For instance, we write $[C^{goal}, C^{object}, D^{agent}_{tdistr}]$ for the above construction of the representation ($4a_{rep}$'). We think that, with respect to the construction of the representation ($4d_{rep}$) of the *carrying balls from London to Rome*-example, we can do without explicitly rendering the construction steps. This would be more or less a repetition of the "unifying in" described above. So, we just mention that we can construct ($4d_{rep}$) via $[C^{goal}, C^{source}, C^{agent}, C^{object}]$. For this construction, the incorporated Aktionsart calculus computes in turn the values *hom, hom, hom, het, het*, where the first value comes from the lexical entry of the verb and the last evaluates the sentence representation. The other values are assigned to the intermediate event descriptions.
Representing names as follows

- $\boxed{\text{Paola}}$

$$\longrightarrow \quad < \text{paola}, \lambda < \varepsilon_{[akt:A]}, \text{DRS}_{[\ldots\text{paola}\ldots]} > \left[< \varepsilon_{[akt:A]}, \text{DRS} \cup \boxed{\begin{array}{c}\text{paola}\\ \hline \\ \end{array}}_{[\ldots]} > \right] >$$

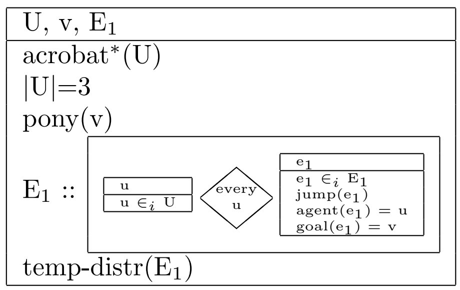
we construct the different readings of the *Paola caressing two cats*-example (8d) discussed in the last section, i.e. ($8d_{rep}$) and ($8d_{rep}$') via $[C^{agent}, C^{object}]$ and $[C^{agent}, D^{object}_{tdistr}]$ respectively. The Aktionsart calculus entails *hom* in the first case and *het* in the second. The transition from any given Aktionsart to *het* in the case of temporally distributed numeral-NPs is justified by the fact that the number of objects that partake as fillers of the NP-role in the introduced event sum E is definite such that subsums of E and also sums that contain E, of course, normally show another number of partaking objects and, therfore, cannot be described by the same event type. In particular, this type cannot be of the form ITER(Q).

As it stands, our construction algorithm runs into problems with respect to the preferred homogeneous readings of examples like (4b) and (4c), ($4b_{rep}$) and ($4c_{rep}$), or with respect to the following heterogeneous (12).

(12) *Drei Akrobaten sprangen auf ein schönes, junges Pony.*
(Three acrobats jumped onto a beautiful young pony.)

A natural reading of (12) is that there is one pony onto which the three acrobats jumped in turn:

($12_{rep_{tdistr}}$)



So, in all three cases, (4b), (4c), (12), there is a reading that distributes over some role. In (4b) this is the *theme*-role, in (12) it is the *agent*-role, in (4c) it is the *object*-role. All of (4b), (4c), (12) introduce a specific goal (Barcelona, the football goal and the pony respectively). The wide scope reading of the goal, which assigns the goal to the sum $E1$, is not sufficient to render the fact that all of the single events $e1$ have the same goal. But the narrow scope reading (with the DRF of the role introduced in the nuclear-scope box) does not render this either, at least not in the case of (12), since here, in contrast to (4b), the goal is not a DRT-constant like *barcelona*, and in contrast to (4c), it is not introduced via a definite description, so that it could be linked to a wide scope antecedent. Note, that DRT claims that DRFs from definite descriptions must be *accessible* from the outside of the sentence DRS, i.e. they must be introduced in the universe of this DRS or they must be linked to an antecedent that is introduced in this position (Kamp and Reyle 1993). This is different in the case of indefinites however. With the narrow scope reading of (12), we cannot be sure that the goal-DRFs introduced for the $e1$-events refer to the same object in the model. The problem can be solved, as is often done, by attributing the status of a subcategorized role to *goal*. In this case, the *goal*-equation, *goal(e)=x*, is part of the DRS introduced by the lexical verb-entry. Then giving the subcategorized *goal-PP* wide scope ensures that the representation of the goal description is part of the main DRS and, in particular, that the goal-DRF is an element of the universe of the main DRS, (though the *goal-equation* is part of an embedded DRS). We will not revise our approach in this respect because there are other roles (source, path, direction) that show similar effects and that, therefore, all had to be subcategorized. There are also other phenomena that suggest searching for a general solution to the problem of protecting (parts of) a role description from being located inside the nuclear scope of a duplex condition that is introduced by the later application of a distributive role. These are the phenomena connected to the cumulative reading.

5. Partial DRSs for Cumulative Readings

We first turn to the *cumulative reading* as such[25], and to its technical prerequesites. From this, at the end of this section, we obtain solutions for the specific problem of the examples (4b), (4c), (12).

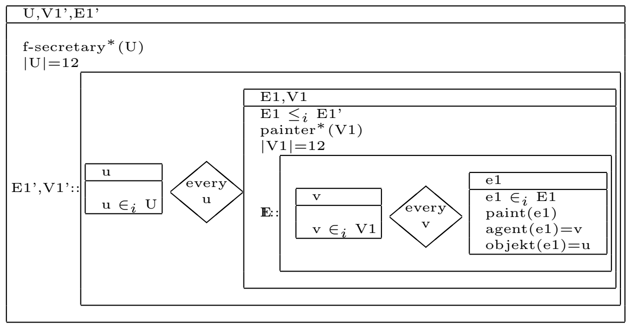
(13) *Zwölf bekannte Maler portraitierten die zwölf EG-Außenminister.*
(Twelve well-known painters painted the twelve EC-Foreign Secretaries.)

The most natural reading of (13) certainly is the one that says that each of the twelve Foreign Secretaries is painted by one or more painters (probably by one) and that each of the painters paints one or more Secretaries (probably one). This is the cumulative reading. Often, the cumulative reading is treated as a specific interpretation of a fairly underdetermined collective reading that, for (13), would only say that there exists an event of painting where twelve painters partake as agents and the twelve Secretaries partake as objects. In the approach suggested in this paper, we cannot treat the cumulative reading as a specific interpretation of an underdetermined collective reading, since our collective reading is rather specific: It entails that the atoms of the role fillers that are sums partake simultaneously in the event. So, our collective reading would only allow for cumulative interpretations that are very specific with respect to the temporal order of the single events that the complex event of the cumulative reading is composed of. However, we think that we do not have to modify our collective reading, because it seems to us that there are reasons for assigning a representation in its own right to the cumulative reading.

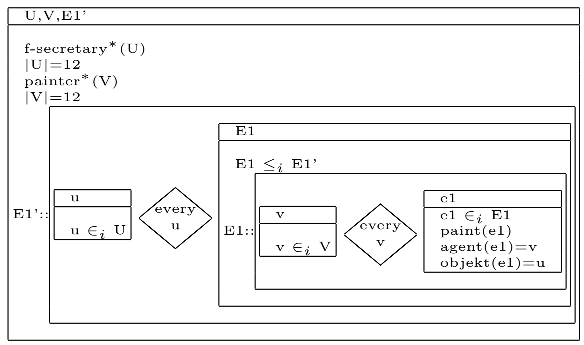
(14) *Die zwölf EG-Außenminister wurden von zwölf bekannten Malern portraitiert, in jeweils einer Woche.*
(The twelve EC-Foreign Secretaries were painted by twelve well-known painters in one week each time.)

We think that the cumulative reading that we have spelled out with respect to (13) is also the natural reading of (14): Each of the twelve Foreign Secretaries is painted by one or more painters (probably by one) and each of the painters paints one or more Secretaries (probably one). However, (14) is more informative than (13). Here, in addition, there is an in-adverbial that comes with the *floating quantifier jeweils*. The impact of floating quantifiers is to call for the distributive reading of a thematic role $TR1$ that is different from the one that introduces the floating quantifier, $TR2$, such that $TR1$ has wide scope over $TR2$ (cf. (Link 1987), (Krifka 1987b)). Thus, *jeweils* calls for the distributive reading of *zwölf bekannte Maler* or of *die zwölf EG-Außenminister*, resulting - in the cumulative perspective - in an analysis that says that for each Secretary (or for each painter) there exists a painting event that took at most one week, and that the sum of painters amount to twelve, (as well as the sum of Secretaries). [26] Provided that the presented cumulative analysis is a natural reading of (14), it is clear that this reading can never be subsumed by a collective reading, independent of how liberally we define collective readings, because in (14) we are forced by the floating quantifier to distribute over at least one of the role descriptions. In order to understand the peculiarity of the general cumulative reading, compare the following representations:

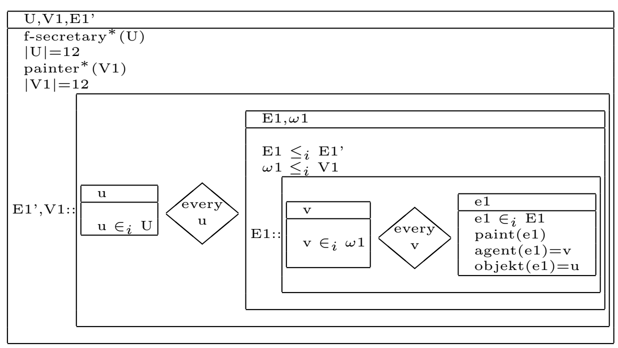
($13_{rep:[D^u(object),D^l(agent)]}$):



($13_{rep:[D^u(object),D^u(agent)]}$):



($13_{rep:[D^u(object),D^{ul}(agent)]}$):



($13_{rep:[D^u(object),D^l(agent)]}$) is the fully distributive reading of (13). This reading can be constructed by means of our algorithm developed in the last section. Here, the introduction and the sortal description of the sum-DRF of the *agent*-role,

,V1
painter*(V1) |V1|=12

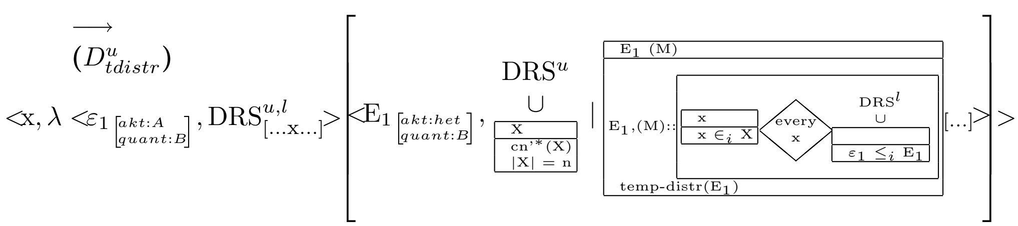
,
is part of the nuclear scope of the duplex condition introduced by the *object*-role. This *agent*-DRS is not introduced at the level of the sentence-DRS (we call this level the *upper* level) but is introduced at a *lower* level. In contrast to this, in the case of ($13_{rep:[D^u(object),D^u(agent)]}$) the same DRS is introduced at the upper level. Its DRF has wide scope with respect to the quantification of the *object*-role. Here,

we obtain the reading that each of the Secretaries is painted by each of the painters. This is a special case of the reading $(13_{rep:[D^u(object),D^{ul}(agent)]})$ which is the desired non-specific cumulative reading. Here, the DRS that introduces the sum-DRF $V1$ of the *agent* and that renders the sortal description of $V1$ is also introduced at the upper level. But, in contrast to $(13_{rep:[D^u(object),D^u(agent)]})$, at the nuclear scope level of the *object*-duplex condition, a DRF $\omega 1$ is introduced that stands for a subsum of a $V1$-interpretation. Here, $\omega 1$, not $V1$, determines the range that the *agent*-role distributes over. Thus, we get the reading that each of the Secretaries is painted by at least one of a sum of twelve painters that has wide scope. Since the abstraction condition $V1 :: \ldots$ ensures that the different $\omega 1$ exhaust the sum $V1$, we infer from this representation also that each of the painters paints at least one of the secretaries. Therefore, $(13_{rep:[D^u(object),D^{ul}(agent)]})$ is indeed the (non-specific) cumulative reading of (13). [27] The superscripts by which we have annotated the labels of the readings of the roles indicate how we will modify the DRS-construction algorithm of the last section in order to account for the two cumulative schemes reflected by $(13_{rep:[D^u(object),D^u(agent)]})$ and $(13_{rep:[D^u(object),D^{ul}(agent)]})$. We will segment each of the DRSs of the NP-representations into two DRSs, the upper DRS, DRS^u, and the lower DRS, DRS^l. Upper DRSs will be protected from falling inside the nuclear scope of a duplex condition. Since sometimes it will be advantageous to have a D^u- or a D^{ul}-reading replaced by the corresponding collective reading, we split up all of our NP-representations of the last section in ${}^u-$, ${}^l-$ and ^{ul}-readings, except, of course, the representation scheme of singular NPs, where the ^{ul}-reading is identical to the ^{u}-reading. In the following we render the six readings that we obtain this way from the D_{tdistr}-readings of numeral and bare plural NPs. We use '|' in order to separate the upper and the lower DRS of the resulting representation. $DRS^{u,l}$ designates the pair of DRSs $< D^u, D^l >$ of the semantic argument.

- $\boxed{\text{n cn}}$, where $n \in DET_{\left[\begin{smallmatrix} num=pl \\ quant=ind \end{smallmatrix}\right]}, n \neq \emptyset, cn \in NOUN_{\left[\begin{smallmatrix} num=pl \\ type=count \end{smallmatrix}\right]}$

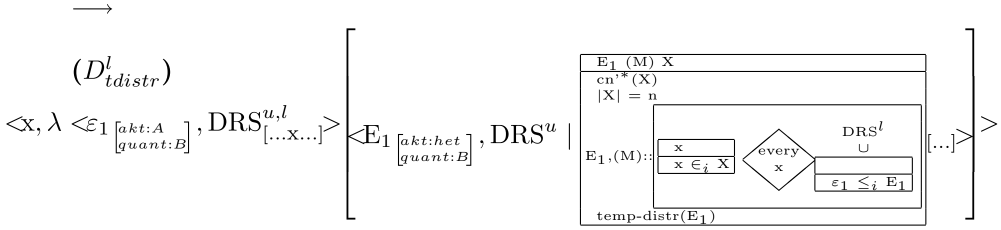
$\longrightarrow$

(D^u_{tdistr})



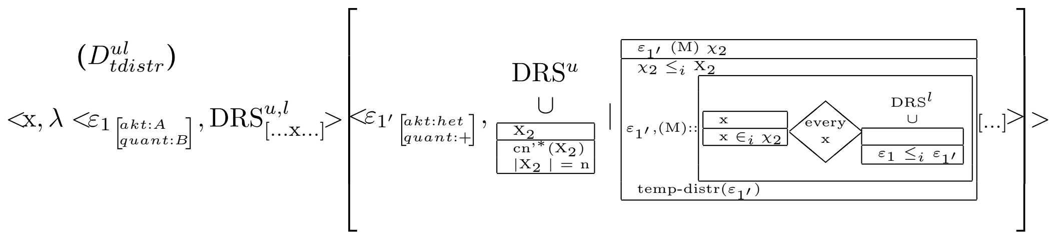
$\longrightarrow$

(D^l_{tdistr})



$\longrightarrow$

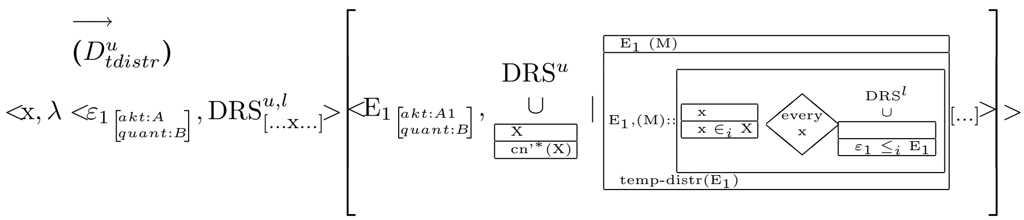
(D^{ul}_{tdistr})



• $\boxed{\emptyset \text{ cn}}$, where $cn \in NOUN_{\left[\begin{smallmatrix} num=pl \\ type=count \end{smallmatrix}\right]}$

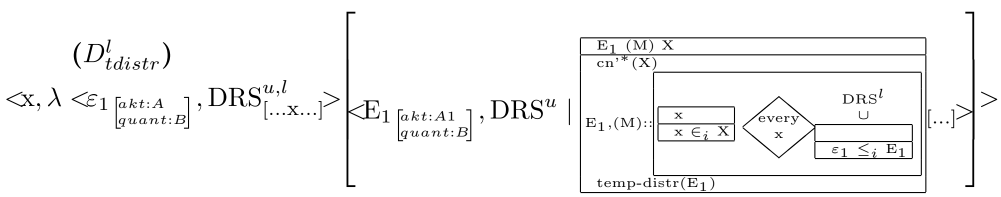
$\longrightarrow$

(D^{u}_{tdistr})



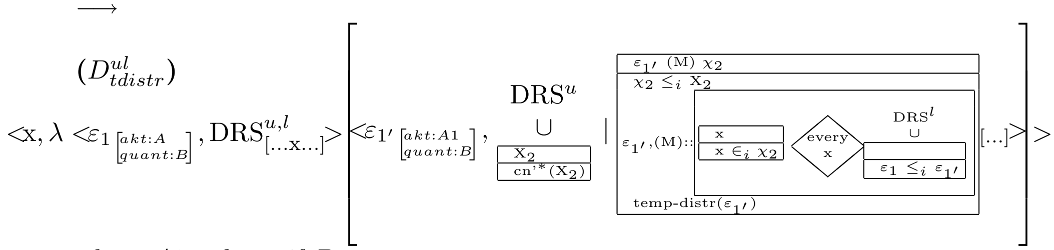
$\longrightarrow$

(D^{l}_{tdistr})



$\longrightarrow$

(D^{ul}_{tdistr})

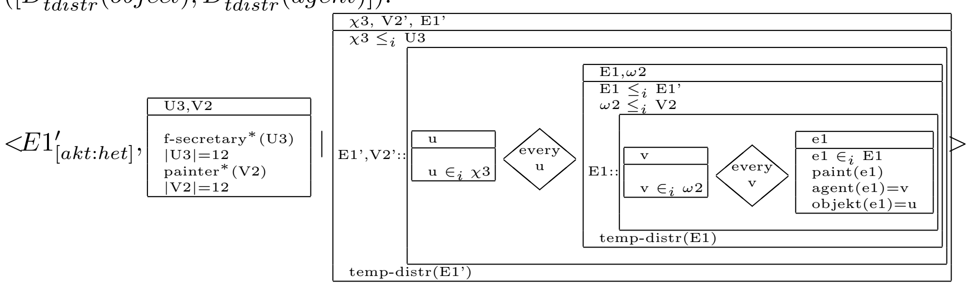


where $A1 = hom$, if $B = -$
and $A1 = het$, if $B = +$

Considering the further above mentioned linking constraints of definite descriptions, it suffices to assign $^{u}-$, $^{ul}-$representations to definite NPs. Also it is clear, that we require that the entry for the verb puts the verb representation into the lower DRS. Thus, the upper DRS of the verb entry is empty. We will not offer examples of the intermediate steps of the construction of a sentence representation.

This would be similar to the illustrative construction of the last section in particular with respect to the unifications made. Instead of this, we concentrate on the final step of constructing ($13_{rep:[D^{ul}(object),D^{ul}(agent)]}$) in the more specific version that uses the *tdistr*-readings. Generally, the constructions $[D^{u}(object), D^{ul}(agent)]$, $[D^{l}(object), D^{ul}(agent)]$ and $[D^{ul}(object), D^{ul}(agent)]$ should result in the same representation. The differences between these constructions should affect the reading only if there is an additional role that could exploit the different behavior of the upper and the lower DRS via a new duplex condition. So, what must we do, for instance, in order to turn the result of $[D^{ul}(object), D^{ul}(agent)]$ into the representation ($13_{rep:[D^{u}(object),D^{ul}(agent)]}$) that we have depicted further above?

($[D^{ul}_{tdistr}(object), D^{ul}_{tdistr}(agent)]$):



Obviously, the last construction step consists of unifying the DRFs that are annotated by the same number ($\chi 3$ with $U3$, $V2'$ with $V2$) and by carrying out the DRS-union with respect to the upper and the lower DRS. With respect to the Aktionsart, some minor reflections make clear that the splitting up into $^{u}-, ^{l}-$ and ^{ul}-readings of the NPs should have no effect. The final construction step shows that this is so, at least with respect to the role that is applied last. [28] However, this does not entail that, with respect to the Aktionsart, constructions using the new representations behave like constructions using exclusively the ones of the last section. Consider the following example:

(15) *Reporter sprachen mit den zwölf EG-Außenministern.*
(Reporters talked to the twelve EC-Foreign Secretaries.)

Here, the construction via $[D_{tdistr}(agent), D^{u}_{tdistr}(object)]$ should entail the Aktionsart-value *hom* for the corresponding reading, because a homogeneously distributed sum E of events that we can describe by *a reporter talks to the twelve Foreign Secretaries* is introduced. Thus, subsums of E that are admissible with respect to a suited grid of E, summing up such events, also are *reporters talking to the twelve Secretaries*-events. In contrast, the construction via $[D_{tdistr}(agent), D^{ul}_{tdistr}(object)]$ should entail the value *het*, because, here, the homogeneously distributed sum E consists of events that we can describe by *a reporter talks to some of the twelve Foreign Secretaries*. This means that admissible subsums of E are not necessarily *reporters talking to the* **twelve** *Secretaries*-sums. Omitting for a moment the definite description of the twelve Secretaries, we see that in the case of $D_{tdistr}(agent), D^{l}_{tdistr}(object)]$, as in the first case, the construction should entail *hom*, because, here, E consists of events that we can describe by *a reporter talks to twelve Secretaries*, as admissible subsums of E do. For E, as well as for subsums, the total number of secretaries is unknown and, therefore, admissible subsums of E satisfy to this reading of (15) (with *zwölf Außenministern* instead of *den zwölf EG-Außenministern*), just as E itself does. Passing over some minor additional reflections with respect to the other NP-representations, we conclude from this, first, that the *tdistr*-distributive reading of bare plurals should turn *het* into *hom* if and only if the event type P of the resulting E does not make use of a ^{ul}-reading of a numeral NP. In order to keep track of this information we use the feature *quant*. The verb entry introduces the value "-" for this feature. This value is changed only by ^{ul}-readings of numeral NPs as rendered in the representations above. We easily see that the value of this feature is relevant only with respect to the *tdistr*-readings of bare plural NPs. For (15), we obtain the Aktionsart-value *hom* also, for instance, with respect to the readings constructed via $[D_{tdistr}(agent), C^u(object)]$ or $[C(agent), C^u(object)]$. We get the value *het*, for instance, with respect to the readings constructed via $[C(agent), D^{ul}_{tdistr}(object)]$ or $[D_{tsim}(agent), D^{ul}_{tdistr}(object)]$.

Summarizing, we notice that the application of *tdistr*-distributively read numeral-NPs entail the *akt*-value *het*, that the application of *tdistr*-distributively read bare plural-NPs entail the *akt*-value *hom*, provided that the actual *quant*-value is "-", and that all the other readings, including the *tdistr*-version of bare plurals in the case of *quant=+*, do not change the incoming *akt*-value.

Considering the constructions of (15), we note that we encounter technical problems with respect to our definition of the *temp-sim/temp-distr*-predicates. Obviously, when stating that the entire event of the description, E, must be temporally distributed, *temp-distr(E)*, we do not want to refer to the single events that the sum E is composed of, as we do, but we want to refer to **those** subsums that we obtain from the event description of **that** embedded DRS that is next to the E-describing DRS with respect to the recursive definition of DRSs. The same is true in the case of *temp-sim(E)*. We can remedy this shortcoming by restricting the *temp-distr/temp-sim*-requirements introduced by a particular role f with respect to a sum E to those subsums of E that are described by the event type that we obtain from the nuclear scope of the duplex condition introduced by the role f. We skip formally spelling out this correction.

Splitting up PP-representations according to the splitting up of the NP-representations presented, with the role equation (or role relation) put into the lower DRS, we arrive at our homogeneous representations (4b$_{rep}$) and (4c$_{rep}$) of the examples (4b), *Olympics fans going to Barcelona*, and (4c), *at the forward-training Völler hitting balls into the goal*, for instance, via $[D^{l}_{tdistr}(theme), C^u(goal)]$ in the first case and via $[C^u(agent), D^{ul}_{tdistr}(object), C^u(\oslash)C^u(goal)]$ in the second. Via $[D^{l}_{tdistr}(agent), C^u(goal)]$, we also obtain the heterogeneous ($12_{rep_{tdistr}}$).

We add two more refinements, aiming at the lexicon, that further adjust the applicability of the algorithm. The cumulative reading that we can construct show a certain asymmetry. We cannot truly represent the reading (*) of (16) that, as (Scha 1981) points out, is the most natural reading of (16).

(16) *600 Dutch firms own 5000 American computers.*
(*) There is a number of collections of Dutch firms such that each collection owns

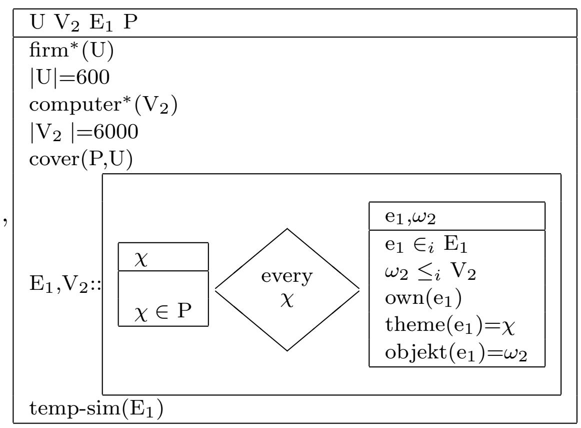
a collection of American computers, and such that the total of the Dutch firms amounts to 600 and the total of the computers amounts to 5000.

We can represent readings, where in the nuclear scope of the duplex condition of the distribution a collection is introduced, but not readings where in the restrictor of the duplex condition a collection is introduced also, as needed in (*). In order to cope with cases like (*), we stipulate:

- for all sums X, for all sets P: *cover(P,X)*$\leftrightarrow sup_i(P) = X$

We skip the obvious generalization of the distributive reading of roles that we obtain from this, and immediately render the satisfying result of applying this to (16):

(16_{rep}) $< E_{1[akt:hom]},$



$>$

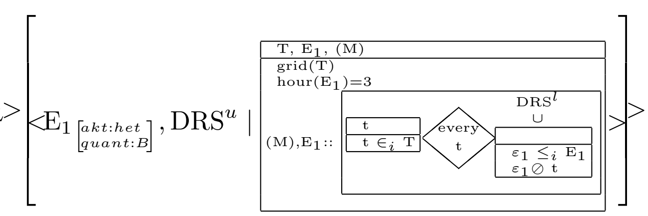
In section 3, using the example of for-adverbials, we discussed how the cooperative behavior of the recipient of the utterance can turn one event description into another via *type coercion*. With respect to those contexts where this change in the event type seems to be fairly regular, it appears to be good policy to incorporate corresponding constraints into the representation of those contexts. For illustration, we consider the context that is provided by for-adverbials.

- 3 Stunden lang

$\longrightarrow$

$(D^l_{tdistr}(duration))$:

$<\_, \lambda <\varepsilon_1 \left[\begin{smallmatrix} akt:het \\ quant=B \end{smallmatrix}\right], DRS^{u,l}{}_L>$



We have skipped to represent the normal case where the incoming Aktionsart-value is *hom*, $(C^l(duration))$. In this case, the incoming event description is changed only by adding the duration statement. Doing this, of course, determines the Aktionsart-value of the outgoing event description to be *het*. In contrast, in case the incoming event description is *het*, it must be modified. Normally, this is effected by iteration. It is this kind of type coercion that we have rendered. Another possibility could be the progressivization of the event description. We presented the ^{l}-reading only, since it is the most/only acceptable reading of a duration statement of the type *for XX TIME-MEASURE* with or without type coercion. We stress, that applying iteration to an event type P is different from restricting P by means of a *temp-distr*-condition. With respect to the extension of P in the model, we obtain in the second case a subset of the extension of P, in the first case we do not.

The refinements of this section contribute to further increase the number of readings. For efficient text understanding this poses a problem. Psychologically, in most contexts, it seems justifiable to analyze event types at a level that abstracts from the *temp-distr/temp-sim*-distinction. In this psychological perspective of the recipient of the text, the *temp-distr/temp-sim*-alternatives can be seen as specifications of a given type that one gets aware of only if the context focuses on disambiguating constraints. Taking this point of view one step further, investigations on text understanding will comprise relating the means for a detailed analysis of situations that we have developed in this paper to suggestions of underspecified representations like (Reyle 1993) and to spell out the conditions that necessitate a precise determination of a particular situation considered. But this is outside the scope of this paper.

6. Conclusion

In this paper we have outlined a DRS-construction algorithm that copes with different readings of plural NPs. This algorithm comprises an Aktionsart calculus that parallels the construction of the semantic representation. We have presented a definition of temporally discourse-homogeneous and temporally discourse-heterogeneous event types. Here, we have used the formal analysis of some sample sentences that make use of plural NPs and that are critical with respect to the Aktionsart in order to spell out a definition of these notions that is also applicable to the case of event types that refer to event sums. Based on this definition, that can deal with different levels of granularity, the main result was, that, for non generic sentences, event roles that are described by bare plurals turn heterogeneous event descriptions into homogeneous descriptions only if, first, they are interpreted in a reading that we have called the temporally distributive reading, and, second, if there exists no other event role that suspends the effect of homogeneity that comes with this specific distributive reading of bare plurals. Only quantized NPs in the so called ^{ul}-readings can suspend this effect. In contrast to this, the temporally distributive, and, from this, also the non further specified distributive reading of quantized NPs turn homogeneous event descriptions into heterogeneous descriptions. Thus, our approach presents a rather differentiated account of the Aktionsart phenomena connected to plural phrases.

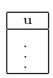
Notes

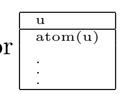
[1] A distinction is often drawn between the Aktionsart and (morphological) *aspect*, where the latter stands for things expressed by the *imparfait* :: *passé simple*-opposition in French or the difference between *simple past* and *past progressive* in English. Notwithstanding such definitions, for the sake of simplicity, we will not distinguish between *aspect* and *Aktionsart* in this paper.

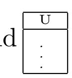
[2] Since achievements combine more easily and with less deformation of the initial 'normal' meaning with in-adverbials than with for-adverbials, we have classified them as heterogeneous descriptions. This is also justified by the similarity to accomplishments in the presence of a number of other Aktionsart sensitive phenomena.

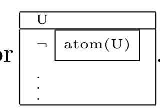
[3] Of course, specific additional contextual information might alter this outcome. For instance, (4a) is easily accepted in the scope of a for-adverbial, if the peculiarity of the Olympics tradition with several sportsmen partaking in one event of taking the torch from Athens to the place of the games is suspended in favor of a reading where the torch is taken to Barcelona several times, each time by a different sportsman.

[4] For a discussion see in particular (Link 1983), also (Schütze 1989), (Link and Schütze 1991), (Krifka 1987b), (Krifka 1987a), (Kamp and Reyle 1993) but, for a controversal debate, also (Landman 1989a), (Landman 1989b).

[5] Thus, 

is an abreviation for 

and 

is an abreviation for 

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[6] Compare for instance (Eberle 1991), where, on the basis of the *feature logic with subsorts* presented in (Smolka 1988), a language for sort expressions (including the *-operator) is developed which is used to attribute rather fine-grained sortal information to the DRFs of DRSs, thus allowing for specific and efficient inference procedures for text representations.

[7] To this point, again, compare (Eberle 1991). For alternative approaches see also (Galton 1984), (Galton 1987), (Löbner 1988).

[8] For simplicity, we will use the term *event* not just for events proper (accomplishments and achievements), but also for states and activities and sums of events, activities or states. The intended meaning should be clear from the context. Also, we mention that, properly speaking, in this approach the terms *accomplishment, achievement, activity* and *state* refer to event types, not to the events themselves. So, more precisely, the term *event* can refer to single objects that are instances of predicates that are instances of some Aktionsart class, and it can refer to sums of such objects.

[9] For instance, a branch b of a tree t is a material part of this tree ($b \leq_m t$): the substance of b is contained in the substance of t. However, it does not hold $b \leq_i t$, since t lacks the internal structure that determines t as a sum that could subsume b as an atom.

The structuring using both $\leq_m$ and $\leq_i$ developed in (Eberle 1991) and used here, is based on the work of Link about objects and portions of matter ((Link 1983), (Link 1984), (Link 1991)).

For an exhaustive description of the formal means that are introduced in the following, as mentioned, compare the more detailed study in (Eberle 1991).

[10] We do not want to deeply motivate different ontological levels for events here. For clarification, think of the well-known example that Bach has used in order to distinguish between materially identical, but otherwise different events:

(17) *Jones poured poison into the water main*$_{e_1}$.
versus
Jones poisoned the populace$_{e_2}$. (Bach 1986)

In Bach's scenario the events e_1 and e_2 refer to the same physical entity, but they function as different events. In order to model such scenarios, we can use interpreting models (text-worlds) that are structured by means of distinguishing criteria that go beyond the level of the pure physical appearence, that include, for instance, intentionality and elements of agent centered action theory. With respect to such models, event descriptions like those of (17) might refer to different events, even if these events are physically equivalent in one way or the other. With the notion of *material part* and the relation of material equivalence that is defined from this notion, we reach the level of such fine-grained interpreting models and can state, for instance, that in (17) it holds $e_1 =_m e_2$ and $e_1 \neq e_2$.

[11] Of course, the threshould value of a complex event predicate should be computed from the value of the underlying simple event predicate that stems from the representation of the verb used in the corresponding natural language description. Normally, we obtain $limit(\lambda e P(e)) = limit(\lambda e(\exists x(P(e) \wedge R(e) = x)))$. To a certain extent, however, the computation should take into account the granularity changing influence of particular thematic roles. (Compare *running of an ant*-events to *running of an elephant*-events in this respect.)

[12] The threshould value for an event predicate refers to the 'volume' of events rather than to the occurrence time, since, as it seems, the perceptibility of the realization of a particular event type depends not only on the temporal dimension but also on some non-temporal criteria. For instance, consider the type *working*. An action that shows a lot of movements on the part of the agent per time unit probably fulfills the decisive features of *working* in shorter time than a less intense instance of the same type, that shows less movements per time unit. This difference in 'spatiality' should have an impact on the definition of the *size*-function.

[13] The contrast (8f) - (8g) has also been used in the ontological considerations of (Shoham 1987).

[14] For degrees of granularity, compare also (Hobbs 1985).

[15] Suggestions for a quantificational analysis of duration adverbials can be found, for instance, in (Dowty 1979), (Hoepelman 1979), (Reyle 1987). But, for a critical position, compare also (Krifka 1987b).

[16] In (Ogihara 1990), (Kamp 1990), (Caenepeel and Moens 1991), data are discussed that seem to suggest that the possibility of conceptualizing a described situation as a single event is closely related to the (semantic) acceptability of applying progressivization to the corresponding natural language description.

[17] Compare section 2, point 6 of the truth conditions.

[18] The definite descriptions *beim Stürmertraining* and *ins Tor* indicate that for a more precise rendering of the event type referred to in (4c), we should also make use of this formal means, the parameterization, with respect to $P2$. We omit this.

[19] We use *type coercion* as introduced in (Moens and Steedman 1988), but applied to event types, not to events.

[20] Having a closer look to the definition of *ITER*, we see that the second representation does not completely correspond to the first one: for simplicity, here, we have omitted to make sure that for different intervals t, t' we obtain different overlapping events e, e' ($t \oslash e$ and $t' \oslash e'$).

[21] Cf. (Verkuyl 1972) for the notion.

[22] Compare (Reyle 1985), (Reyle 1987), or (Zeevat, Calder and Klein 1987) to a more detailed motivation of indices.

[23] For partial DRSs, compare also (Reyle 1987), (Eberle 1991), (Kamp and Reyle 1993).

[24] This inversion is often advocated in the literature on unification-based grammar formalisms. For an example of an application compare, for instance, (Bouma 1989).

[25] Compare, for instance, the detailed studies (Scha 1981), (Scha and Stallard 1981) on this subject. We stress that the cumulative reading of a sentence must not be confused with the cumulative extension of a predicate in the model. Until now we have used the notion only in the second sense.

[26] Properly speaking, we think that in the case of (14) it might be that we have to quantify over the situations introduced by the entire event rather than to quantify over the atoms of the sum introduced by the description *zwölf bekannte Maler* or by the description *die zwölf EG-Außenminister* respectively, since the meaning of the adverbial seems to be that each of the single events that compose the entire event of (14) took at most one week. But this formal analysis indirectly requires the distribution over at least one of the role descriptions and corresponds to the outlined analysis in substance.

[27] As in sections 3 and 4, the conditions of the type $e1 \in_i E1$ and $E1 \leq_i E1'$ in the above representations guarantee that $E1, E2$ are not necessarily maximal sums with respect to the event types that characterize them.

[28] It is true that, in the D^{ul}_{tdistr}-case of numeral NPs and in the D^{u}_{tdistr}-case of bare plural-NPs, the event type corresponding to the representation of the lower DRS developed at the particular intermediate construction step of applying the respective role entails the "wrong" Aktionsart value. But we think that the human recipient of the sentence does not evaluate these event types as such, but augments them according to the information presented by the actual upper DRS. This means that he interprets the result of the actual role application more or less like the result of a last role application. This can be modelled formally in order to prove the correctness of the algorithm suggested in this section.

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