A Dynamic Logic of Events and States for the Interaction between Plural Quantification and Verb Aspect in Natural Language

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Abstract

The influence NPs can have on the aspectual behaviour of verbal expressions, witness the pair 'eat an apple in ten minutes/*for ten minutes' and 'eat apples *in ten minutes/for ten minutes, requires an analysis of how static semantic information (NP) interacts with dynamic semantic information (verb). An interpretation of verbs and NPs is presented in which the interaction is analyzed by using an extension of dynamic logic (DL). First, models for DL are extended by adding a domain E of events (together with an event structure $\mathbf{E}$). The intuition behind this addition is that each transition (pair of states) which is an element of the relation denoted by a program in DL is brought about by an event from E. This makes it possible to view a change either as an object (event) or as a transformation of a state. Second, in addition to sequential programs, parallel programs (relations between sets of states) are introduced. At the level of $\mathbf{E}$ this corresponds to the distinction between events and sets of events. The dynamic component of a verbal expression denotes an event-type P that corresponds to a program (relation between states) at the level of the transition structure $\mathbf{S}$. This program has particular properties in terms of which aspectual distinctions are defined. The parallel program corresponding to sets of events is partly determined by the cardinality information introduced by the determiner as part of an argument NP. At the level of $\mathbf{E}$ this information functions as a boolean condition expressing the result that is brought about by the set of events. Static information therefore interacts with dynamic information by providing a condition that must hold upon termination of events.[1]

1 Data and Evidence

A central task of any theory of aspect is to explain the distribution of *in*- and *for*-adverbials on the basis of a semantic analysis of verbs and noun phrases. This distribution depends on at least the following factors. First, there is the contribution made by the verb.

(1) a. eat an apple in ten minutes/*for ten minutes
    b. push a cart *in ten minutes/for ten minutes

Although the semantic properties of the NPs are identical (disregarding the difference with respect to the head noun which is aspectually not relevant), the distributional pattern is different. It it therefore necessary to distinguish between a verb like

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'eat' that admits of modification with an *in*- but not of that with a *for*-adverbial for singular, non-mass arguments and a verb like 'push' for which modification with a *for*- but not with an *in*- adverbial is possible if the arguments are singular and non-mass. According to the Vendler-classification, 'push' is an activity-verb and 'eat' is an accomplishment-verb. Second, there is the contribution made by an argument NP. Here three cases must be distinguished: (a) singular (non-mass) NPs, (b) non bare plural NPs (five carts, two apples) and (iii) bare plural NPs (carts, apples). The first case is identical to that concerning the verb discussed above. For the case of non-bare plural NPs, the distributional pattern depends on the way the action is executed.

(2) a. push five carts in ten minutes/for ten minutes
  b. push five carts successively in ten minutes/*for ten minutes
  c. push five carts simultaneously *in ten minutes/for ten minutes
  d. Five boys pushed a cart in ten minutes/for ten minutes.

If the underlying verb is an activity-verb like 'push', modification with an *in*-adverbial is possible if the action is done in a non-simultaneous way. For instance, if the five carts are pushed one after the other, only modification with an *in*-, but not with a *for*-adverbial is possible, (2b). If, on the other hand, the carts are pushed simultaneously, modification with an *in*-adverbial is excluded, similar to the case of singular, non-mass arguments, (2c). (2d), finally, shows that non-bare plural NPs in external argument position too can trigger modification with an *in*-adverbial. Each boy pushed a cart and they pushed the cart(s) successively. For an accomplishment-verb like 'eat', the aspectual behaviour does not depend on the way the action is executed. The distributional pattern is the same as that in the case of singular, non-mass arguments.

(3) a. eat five apples successively in ten minutes/*for ten minutes
  b. eat five apples simultaneously in ten minutes/*for ten minutes

For verbs that are neither accomplishments nor activities one gets a pattern that is similar to that for activity-verbs.

(4) a. hate a yuppy at noon/*in ten minutes/for a week
  b. hate simultaneously three yuppies at noon/*in one year/for one year
  c. hate successively three yuppies *at noon/in one year/*for one year

(5) a. discover a solution at noon/in ten minutes/*for ten minutes
  b. discover simultaneously two solutions at noon/in ten minutes/*for ten minutes
  c. discover successively two solutions *at noon/in ten minutes/*for ten minutes

(6) a. knock at the door at noon/*in ten minutes/*for ten minutes
  b. knock simultaneously at three doors at noon/*in ten minutes/*for ten minutes
  c. knock successively at three doors *at noon/in ten minutes/*for ten minutes

Stative verbs like 'hate' admit both of modification with an *at*- and with a *for*-adverbial if the arguments are singular and non-mass, whereas modification with *in*-adverbials is excluded. This pattern is not changed for non-bare plural arguments and simultaneous executions. Yet, for non-simultaneous executions, only modification with an *in*-adverbial is possible whereas the other two types of temporal adverbials are excluded, again similar to the case of an activity-verb like 'push'. For achievement-verbs like 'discover' and point-verbs like 'knock' the situation does not change. For simultaneous executions one gets the same pattern as for the case of singular, non-mass arguments. If the action is executed non-simultaneously, only modification with an *in*-adverbial is possible.

The third case is given by bare plural NPs. VPs with bare plurals (almost) always admit of modification with *for*-adverbials, independently of how the action is executed and independently of the aspectual class to which the verb belongs.

(7) eat apples/push carts/hate yuppies/discover solutions/ knock at doors (simultaneously, successively) *in ten minutes/for ten minutes

If a bare plural occurs in external argument position, one gets the same behaviour.

(8) a. Students crossed the street *in an hour/for an hour.
b. Farmers pushed a cart *in an hour/for an hour.
c. Syntacticians hated five yuppies *in one year/for one year.
d. Tourists discovered this quaint little village *in one year/for years.
e. Beggars knocked at this door *in ten minutes/for ten minutes.

The examples in (9a,b) show that the presence of a bare plural does *not* necessarily exclude modifiability with an *in*-adverbial. Rather both types of modification are possible, (9c). Example (9d), finally, shows that in some cases modification with a *for*-adverbial is excluded.

(9) a. John filled the bottle with marbles in ten minutes.
b. Mary loaded the truck with apples in one hour.
c. John filled the bottle with marbles for ten minutes. Then he had to stop because there were no more marbles.
d. Soldiers killed Bill in ten minutes/*for ten minutes.

(9c) shows that modification with a *for*-adverbial does not necessarily require a repetitive reading of the sentence. As the second sentence makes clear, the bottle is not completely filled but only to a certain degree because there were not enough marbles to completely fill it. In such a situation 'John filled the bottle with marbles' can be paraphrased by 'John put marbles into the bottle'. Modification with a *for*-adverbial is excluded if the object that undergoes the change can be subjected to this type of event only once, (9d).

In the sequel modifiability of an expression with an *in*-adverbial will be called terminativity. Modifiability of an expression with a *for*-adverbial will be called durativity. The discussion of the above data can be summarized in the following four observations.

(i) singular, non-mass NPs do not give rise to a terminative reading with activity-, point- and stative-verbs (1b), (4a)-(6a)

(ii) non-bare plural NPs can lead to a terminative reading with activity- as well as with point- and stative-verbs if the action is done non-simultaneously, independently of the argument-position, (2c,d), (4c)-(6c)

(iii) if the expression contains an accomplishment-verb, one gets a terminative reading if no bare plural is present but independently of the way the action is executed, (1a) and (3a,b)

(iv) bare plurals (almost) always admit of a durative reading, independently of how the action is done and independently of the aspectual class to which the underlying verb belongs, (7) and (8)

From these observations the following conclusions can be inferred.

(a) the contribution of non-bare plural NPs depends on the temporal order in which the action is executed: simultaneous vs. non-simultaneous
(b) the contribution of bare plural NPs does not depend on the temporal order in which the action is executed
(c) the contribution of plural NPs does not depend on the argument-position

The task consists in finding a (formal) analysis of verbs and NPs that explains the distribution of *in*- and *for*- adverbials in (1) - (9) on the basis of the observations in (i) - (iv). In particular, it must be shown how the atemporal semantic properties of NPs can have an influence on the semantic (temporal, aspectual) properties of verbs (verbal expressions). The central problem that any analysis of the above data faces therefore is that temporal (verbal) and non-temporal (nominal) information must be combined.

2 Changes as Objects and Changes as State Transformers

In Naumann (1996,1997a,1997b,1998) and Naumann/Mori (1998) a theory of aspect has been developed that is based on the intuition that non-stative verbs express changes. The intuitive notion of a change comprises at least two perspectives that are complementary to each other.

(i) something (an object: event, action) which brings about the change
(ii) something (a result) which is brought about by the change that did not hold before the change occurred (transformation of states)

In (i) 'change' refers to the sense captured in (ii), i.e. change as a result, whereas in (ii) 'change' refers to the sense captured in (i), i.e. change as an object. Thus, (i) can equally be formulated as 'something (an object: event, action) which brings about the result (transformation of state)' and (ii) as 'something (a result) which is brought about by the event (action) that did not hold before the event (action) occurred'. The first perspective is captured in event-semantics (ES), Krifka (1989, 1992), where the domain E of events can be interpreted as representing changes as objects. What is missing (or only implicit) in ES is the second perspective of a change as a transformation of state that brings about a particular result. This perspective is captured in Dynamic Logic (DL). Program-letters π are interpreted as binary relations on the underlying domain S of states. If $(s, s') \in R\pi$, this means that executing the program π in the input-state s the output-state s' is reached (or can be reached, if the program is non-deterministic). Thus, in DL program-letters function as labels with which transitions between states can be decorated. Interpreting the transitions as accessibility relations between states, this means that each program-letter defines an accessibility relation on S. The disadvantage of DL consists in the fact that there are no objects in the model that are interpreted as changes. There is no domain of, say, events the elements of which are taken as bringing about the transformation of some input-state s into some output-state s'. The program-letters π, being interpreted as simple input/output-relations, cannot be taken to denote changes as objects.

What is needed is a combination of both perspectives. On a combined perspective the eating of an apple can be interpreted in the following way. At the level of a change as an object it is an event of type eating, whereas at the level of a change as a transformation of state some (input-) state s in which there is a complete apple is transformed into a (n output-) state where the apple does not exist (has vanished). The result ϕ that is brought about by the event of type eating therefore is that the apple ceases to exist. The pushing of a cart, on the other hand, is analyzed as an event of type pushing which transforms some (input-) state s into a (n output-) state s' such that relative to s the cart traversed a non-empty path.

Models for the language consist both of a transition-structure **S** (with an underlying domain S of states) and an eventuality-structure **E** (with an underlying domain E of events). Whereas the transition-structure **S** corresponds to the perspective of changes as transformations of states, the eventuality-structure **E** is used to model the perspective of changes as objects. The decisive step5 consists in combining both structures with each other. First, to each event $e \in E$ is assigned its source-state $\alpha(e)$ and its target-state $\beta(e)$, respectively. Together, the functions α and β determine the execution-sequence $\tau(e)$ of e. So far it is not possible to make aspectual distinctions between different event-types, e.g. between the event-type P_{eat} of eating events, that belongs to the class ACCO of accomplishments, and the event-type P_{push} of pushing events, that belongs to the class ACT of activities. Events as changes as objects are basic objects. If it is assumed that the execution-sequences of all events $e \in E$ are characterized by the fact that a condition (result) does not hold at the source-state $\alpha(e)$ and does hold at the target-state $\beta(e)$, it is not possible to distinguish different types of changes at that level. Rather, different types of changes are defined at the level of changes as transformations of states. Event-types P_v can be distinguished both with respect to the (type of) result that is brought about and the way this result is brought about. With respect to the result a distinction must be made between minimal and non-minimal results (corresponding to a distinction between minimal and non-minimal changes with respect to the result, see Naumann/Mori (1998)). Consider an event e of type 'eat an apple'. As was already said above, the result brought about is that the apple ceases to exist. This can be expressed by the requirement that at the target-state $\beta(e)$ of e the mass of the apple must be zero. This result is non-minimal in the sense that not for each event $e \in P_{eat}$ it is required that the mass of the object with respect to which it effects a change be zero at e's target-state $\beta(e)$. Rather what is required of all events $e \in P_{eat}$ is that the mass of the object that undergoes the change be less in $\beta(e)$ than its mass in $\alpha(e)$. For an event e of type 'push a cart', on the other hand, the result brought about is minimal: all that is required is that the object denoted by the internal argument (e.g. the cart) traversed a non-empty path (relative to the source-state $\alpha(e)$ of e). This requirement holds for all events $e \in P_{push}$ and therefore expresses the minimal condition that an element of this type must satisfy. This condition is changed by a modifying expression like 'to the station' that strengthens the result to a non-minimal one. It is no longer sufficient that the cart traversed a non-empty path (relative to the source-state) but it must be at the station in the target-state $\beta(e)$ of e. This relationship between an event-type P_v and a result is captured by a function δ that assigns to each P_v a relation between sets of individuals and states. For instance, $\delta(P_{eat}) = \lambda X \lambda s.MASS(X)(s) = 0$ and $\delta(P_{push}) = \lambda X \lambda s.PATH(X)(s) \neq \varepsilon$. For a given X, $\delta(P_v)(X)$ is a property of states, i.e. the result that can possibly be brought about by an event of type v (for more details, see Naumann/Mori, 1998).

From what has been said it follows that (completed) events of type eating differ from those of type pushing with respect to the result. Whereas it is non-minimal for the former, it it minimal for the latter. This is not the only respect in which the two event-types differ. They also differ with respect to the way the result is brought about. Consider again an event e of type 'eat an apple'. The result brought about, the mass of the apple is zero, only holds at the target-state $\beta(e)$ of e's execution-sequence $\tau(e)$ and at no other state of $\tau(e)$. Thus, the result is brought about only at $\beta(e)$ and not before this state is reached.[2] For an event e of type 'push a cart' this is different. The result - a non-empty path is traversed - does not only hold in the target-state $\beta(e)$ of an event e of this type but rather at all non-initial states of e's execution-sequence such that it holds at all states of the execution-sequence except the first one. This relationship between an event-type P_v and the way the result is brought about is expressed by a function γ that assigns to each P_v a so-called dynamic mode, that is, a function that maps a property of states Q to a binary relation on S. In (10), two examples of dynamic modes are given ($<$ is an ordering on S; see the appendix for details).

(10) a. $R_{Min-BEC} = \lambda Q \lambda ss'[s < s' \wedge \neg Q(s) \wedge Q(s') \wedge \forall s"[s < s" < s' \rightarrow \neg Q(s")]]$
b. $R_{\text{Con-BEC}} = \lambda Q \lambda ss'[s < s' \wedge \neg Q(s) \wedge Q(s') \wedge \forall s"[s < s" < s' \rightarrow Q(s")]]$

The dynamic mode $R_{Min-BEC}$ partly characterizes ACCO, the aspectual class of accomplishments whereas $R_{\text{Con-BEC}}$ characterizes the aspectual class ACT of activities.[3] Other aspectual classes are characterized by different dynamic modes, Naumann (1998) and Naumann/Mori (1998). In general, a dynamic mode determines how the result Q is brought about. For $Q = \delta(P_v)(X)$ such that X is the object with respect to which an event $e \in P_v$ brings about the result (i.e. the value of

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[2] One may object, as one of the referees did, that it is not necessary to eat all of the apple. For instance, one can leave the core. Examples like this one show that in some cases the result is context dependent. Yet, after it has been determined what counts as eating an apple in a particular situation, it is true that the result only holds at $\beta(e)$ and at no other state of the execution-sequence. See also the next footnote for a different solution to this objection.

[3] $R_{\text{Con-BEC}}$ is in a sense too simple. E.g., in the case of an event e of running there can be initial stages e' of e that do not belong to P_{run} because, say, the agent only moved one of his feet. Consequently, the result is *not* satisfied for *all* intermediate states of the execution-sequence. This problem can be solved by weakening the mode as follows. What is required is not that the result is satisfied at each intermediate state but only at those states s' such that the sequence $(\alpha(e), s')$ is the execution-sequence of an initial-stage e' of e that is of type P_{run}. This is expressed by the modified dynamic mode in (*) (where $Q = \delta(P)(\rho(P)(e))$ and P ranges over the elements of $\{P_v \mid v \in VERB\}$, $prefix$ is the proper prefix-relation).

(*) $R_{\text{Con-BEC}^*} = \lambda P \lambda e[\neg Q(\alpha(e)) \wedge Q(\beta(e)) \wedge \forall e'[prefix(e', e) \wedge P(e') \rightarrow Q(\beta(e'))]]$

According to (*) a dynamic mode is a relation between event-types, i.e., it is defined directly at the level of changes as objects although the requirement on the result is still expressed as a condition on the target-state of e and on the target-states of its initial-stages e' that are of type P_v.

For events e belonging to an event-type P_v of sort ACCO (*) does not hold. The result need not be satisfied at the target-state of each initial-stage e' that is of type P_v. This difference can be used to give an alternative solution to the objection discussed in the previous footnote. If not all of an apple need be eaten, one gets two different sorts of execution-sequences: those where the core is left such that the result is satisfied only at the target-state and those where the core is eaten such that the result can hold at intermediate states. The difference between the execution-sequences of events of sort ACCO and those of sort ACT concerns the way the result Q is required to be true at initial-stages of type P_v. Events that belong to an event-type of sort ACT require Q to be true for all initial-stages of sort P_v whereas this is not the case for events belonging to an event-type of sort ACCO (for details, see Naumann 1999).

$\rho(P_v)(e))$, $\gamma(P_v)(Q)$ therefore determines the way the result is brought about by e. For a given Q, $\gamma(P_v)(Q)$ is a binary relation on S. This binary relation can be taken to be the interpretation of some (possibly complex) program from DL. For instance, $R_{Min-BEC}(Q)$ is a variant of the **while**-loop, whereas $R_{\text{Con-BEC}}(Q)$ corresponds to an iteration, Naumann (1996, 1998). In what follows possible differences with respect to the result will be disregarded such that event-types are aspectually classified only with respect to the way the result is brought about, i.e. with respect to the function γ. At this level differences between event-types belonging to ACCO (e.g. P_{eat}) and those belonging to ACT (e.g. P_{push}) can be characterized as follows. Aspectually, the execution-sequences of (completed) events can be split into three parts, corresponding to a nucleus-structure, Moens/Steedman (1988).

$$\underset{IP}{|}\;-\,-\,-\,-\,-\,-\,-\,-\,\underset{DP}{-}\,-\,-\,-\,-\,-\,-\,-\,-\;\underset{CP}{|}$$

The inception-point IP corresponds to the source-state $\alpha(e)$, the culmination point CP to e's target-state $\beta(e)$ and the development-portion DP to the states in between $\alpha(e)$ and $\beta(e)$, i.e. DP $= \{s \in S \mid \alpha(e) < s < \beta(e)\}$. The execution-sequences of all (completed) events e are characterized by the fact that the result holds at $\beta(e)$ and fails to hold at $\alpha(e)$. Differences therefore concern intermediate states of the execution-sequence, i.e. elements of the DP. As the dynamic mode assigned to P_{eat} is $R_{Min-BEC}$, it follows that the result is continuously false on the DP, i.e., it holds for no intermediate state of the execution-sequence. For the execution-sequence of events $e \in P_{push}$, on the other hand, the result is constantly true on the DP, i.e., it holds at all states of the execution-sequence. From this one may conclude that the notions of durativity and terminativity can be defined in terms of the dynamic modes $R_{\text{Con-BEC}}$ and $R_{\text{Min-BEC}}$, respectively.

(11) a. $\forall P[DUR(P) \longleftrightarrow \gamma(P) = R_{\text{Con-BEC}}]$
b. $\forall P[TERMIN(P) \longleftrightarrow \gamma(P) = R_{\text{Min-BEC}}]$

(11) is inadequate for the following reasons. First, it will at most account for the distinction between activity- and accomplishment-verbs, i.e. for the distinction between the examples in (1), 'eat an apple in ten minutes/*for ten minutes' and 'push a cart *in ten minutes/for ten minutes'. It leaves unaccounted for why, e.g., a VP like 'reach the station' with an achievement-verb can be modified with *in*- but not with *for*-adverbials although P_{reach} is neither assigned the $R_{\text{Con-BEC}}$- nor the $R_{Min-BEC}$-mode. Second, stative verbs like 'love' or 'be ill' do not have any corresponding event-types because they do not express changes but rather denote the results of the changes expressed by non-stative verbs, Naumann (1998). They are therefore not assigned a dynamic mode by the function γ which is defined only for the event-types P_v. (From this is does not follow that (the interpretation of) stative verbs is not assigned any dynamic mode at all, see below). Third and most importantly, as was shown in section (1), the aspectual behaviour of an expression depends on the semantic properties of the NPs that occur in it such that expressions with the same verb, e.g. 'eat an apple' and 'eat apples', can show a different aspectual behaviour. It is therefore not possible to identify the aspectual behaviour of an expression in which the (non-stative) verb v occurs as main verb with the dynamic mode assigned to the corresponding event-type P_v. This already follows from the fact that the function

γ is defined only for the P_v and not for arbitrary (non-empty) subsets of E. Yet, extending γ to arbitrary (non-empty) subsets of E will not work either because the aspectual behaviour of an event-type P that is a subset of some P_v, say the event-type corresponding to 'eat apples' which is a subset of P_{eat}, should be deducible from the dynamic mode assigned to P_{eat} and the semantic properties of the internal argument NP, i.e. the bare plural NP 'apples' in the example.

What is needed is a generalization of what is captured by the definition of durativity given in (11). Recall that the execution-sequences of events e that belong to an event-type P_v to which γ assigns $R_{\text{Con-BEC}}$ are characterized by the fact that the result brought about by e, i.e. $\delta(P_v)(\rho(P_v)(e))$, holds for all states of the sequence except (possibly) the first one. In terms of the nucleus-structure this means that the result is constantly true on the DP and holds at the CP. From a procedural perspective this means that the result is a kind of generalized invariance property of the execution-sequences of events of type P_v. This can be expressed by using the **G**-operator from Temporal Logic, (12a).

(12) a. $\sigma \models \mathbf{G}\phi$
b. $\sigma \models \phi$ iff $\sigma, 0 \models \phi$
c. $\sigma, j \models \mathbf{G}\phi$ iff for all k s.t. $j < k \leq n : \sigma, k \models \phi$ (where n is the length of σ)

According to (12b), a sequence σ satisfies a formula ϕ just in case it is satisfied at the first element of the sequence. For a given P_v, σ is the execution-sequence of an event $e \in P_v$ and ϕ_1 expresses the result brought about by e (i.e., $[\![\phi_1]\!]$ is the parametrized property of states $\lambda s.\delta(P_v)(\rho(P_v)(e))(s)$, i.e., $\sigma, k \models \phi_1\ [P_v, e]$ iff $s_k \in \delta(P_v)(\rho(P_v)(e))$. The parametrization is expressed by '$[P_v, e]$'). This yields (13).

(13) $\tau(e) \models \mathbf{G}\phi_1\ [P_v, e]$

If an event-type P_v is assigned $R_{\text{Con-BEC}}$ by γ, this means that the execution-sequence $\tau(e)$ of each event $e \in P_v$ satisfies (13). Thus, one gets the property (P1).

(P1) $\forall e \in P_v : \tau(e) \models \mathbf{G}\phi_1\ [P_v, e]$, if $\gamma(P_v) = R_{\text{Con-BEC}}$

(P1) is not satisfied for event-types P_v that are assigned $R_{Min-BEC}$ by γ: $\neg\forall e \in P_v : \tau(e) \models \mathbf{G}\phi_1\ [P_v, e]$ if $\gamma(P_v) = R_{Min-BEC}$. In this case (P1) can fail for two reasons. First, not each event $e \in P_v$ need be a completed event of this type. An event $e \in P_v$ is completed just in case $\beta(e) \in \delta(P_v)(\rho(P_v)(e))$, i.e., if the postcondition (result) determined by δ holds at the target-state $\beta(e)$ of e. Second, even if $\beta(e) \in (P_v)(\rho(P_v)(e))$, (P1) does not hold for all events e that satisfy this condition because the result $\delta(P_v)(\rho(P_v)(e))$ only holds at the target-state of e and at no intermediate states of the execution. If there are any intermediate states at all, (P1) therefore does not hold for a completed event $e \in P_v$ with $\gamma(P_v) = R_{Min-BEC}$. Thus, even the weakened form (P1') of (P1) does not hold for events e of an event-type P_v with $\gamma(P_v) = R_{Min-BEC}$.

(P1') $\forall e \in P_v :$ if $\beta(e) \in \delta(P_v)(\rho(P_v)(e))$, then $\tau(e) \models \mathbf{G}\phi_1\ [P_v, e]$

The invariance-property expressed by $\mathbf{G}\phi$ also holds for the execution-sequences that are denoted by the dynamic component of stative verbs. Although there is no event-type P_v that corresponds to a stative verb v because stative verbs do not express changes, stative verbs have a dynamic component too that defines a binary relation on S the elements of which are characterized by the dynamic mode R_{HOLD} (see the appendix). Similar to the dynamic mode $R_{\text{Con-BEC}}$ the property Q is required to hold at all non-initial states of a sequence such that in this case too $(s, s') \models \mathbf{G}\phi$ holds where ϕ expresses the property Q (in effect, Q must even hold at all states of the sequence such that (P1) can be strengthened to $(s, s') \models \Box\phi$).

According to (13), durativity at the level of verbs (i.e. in the lexicon) can be formally explained as a kind of invariance-property of execution-sequences. The result brought about by the event e holds for all states of e's execution-sequence $\tau(e)$, except (possibly) for the first one. The principle theses to be argued for in this paper can now be formulated as follows.

(i) The notion of durativity is defined for each projection of V. Durativity at a particular projection V^n of V ($n \geq 0$) will be call local durativity (at level n).

(ii) At each level local durativity is explained in terms of some kind of invariance-property of execution-sequences.

(iii) Global durativity at level n is defined in terms of local durativity at lower levels.

Local durativity at level $n > 0$ will be defined in terms of properties of NPs. What are the properties of NPs in terms of which local durativity at higher levels can be defned? In order to answer this question, one first has to answer the question in what the aspectual function of an NP consists on the perspective that non-stative verbs express changes.

The functions γ and δ determine only the binary relation for single events of a given event-type P_v. At the linguistic level this corresponds to verbal expressions in which all arguments are singular and non-mass, e.g. '(John) eat an apple' or '(a boy) push a cart'. If the arguments are plural, either bare or non-bare, the situation is different. Consider the VP 'eat three apples'. In this case the result must be brought about by the agent, say John, for each of the three apples separately. At the level of changes as objects this means that three events must be executed instead of only one in the case of 'eat one apple'. At the level of changes as transformations of states one gets instead of one execution-sequence three execution-sequences, one for each of the three events. Procedurally, this means that instead of a sequential program from DL one gets a parallel program. Thus, in order to account for cases with plural arguments ('John ate five apples', 'Three girls pushed seven carts'), the theory must be extended in a way that is similar to the extension of DL to concurrent DL, Peleg (1987), where in addition to sequential programs one also has programs running in parallel which are interpreted as relations between sets of states, Fernando (1994).

Thus, from the perspective that non-stative verbs express changes, the semantic function of argument NPs consists primarily in determining (or restricting) the number of changes, i.e., the number of events that are executed (or the corresponding number of processes (execution-sequences) that are running in parallel). Consider, for instance, the example 'Five boys pushed three carts'. This sentence has (at least) two interpretations: a distributive and a collective one. On the distributive reading, each of the five boys pushed three carts on his own such that maximally fifteen carts were pushed (if the carts were different on each occasion). In terms of the notion of change each of the five boys must have brought about the result with respect to each of his three carts (the carts traversed a non-empty path). Thus, on the distributive reading one gets a total of $5 \cdot 3 = 15$ events, all of which are of type pushing. On a collective reading, on the other hand, the five boys pushed three carts together such that the total number of carts pushed is three. In this case the total number of events is 3: $1 \cdot 3 = 3$. The cardinality contributed by the external argument NP does not matter. It simply drops out. From this example one can infer the following (simplified) rule for sentences with transitive verbs (for the interpretation of NPs assumed here, see section (3.2) below).

(14) a. [[SPEC DET$_n$] N]$_{NP_{ext}}$ V$_v$ [[SPEC' DET$_m$] N']$_{NP_{int}}$
b. distributive reading: $n \cdot m$ events of type P_v
c. collective reading: $1 \cdot m$ events of type P_v

This way of individuating events may be objected to due to examples like the following. Suppose three carts are touching each other such that pushing one of them causes the two others to move as well. In this situation there seems to be only one event of pushing and not three. This argument mixes up two points that must be distinguished. If all three carts moved, i.e. traversed a non-empty path, there are three transformations of states. This is a necessary condition for a corresponding sentence, say 'John pushed three carts', to be true. On the present analysis to each of these three transformations corresponds an object, i.e. an event, that brought this change of state about. Consequently, there are three events of type pushing. From this it does not follow that the agent, say, John, carried out three different actions (events). Rather, his contribution to the three pushing events is different. Whereas his contribution to the event corresponding to the cart that is directly pushed is immediate (direct causation), his contribution to the two other events is only indirect (indirect causation). If one objects that there is only one pushing because there is only one action executed by John, the sentence 'John pushed three carts' is false because he *pushed* only one cart. The other two carts were not pushed but only moved such that instead of 'John pushed three carts' 'John moved three carts' must be used. Furthermore, the principle of individuation of events that is used here does not exclude to interpret 'John pushed three carts' as denoting a single event. One only has to assume that to each non-empty set of events E' there exists its join $e_{E'}$ that is an element of the domain E of events. If E' is the set of the three pushing events and $e_{E'}$ its join, each element of E' is a subevent of $e_{E'}$. The event $e_{E'}$ can be taken as a kind of 'reification' of the set E'. A similar argument applies to 'John ate two apples' when used to describe a situation in which the apples were chopped up in a bowl. Each apple must be eaten by John although it is possible that by taking some of the apple pie from the bowl John is eating parts of both apples. In this situation the two apples are eaten simultaneously. Again, it is possible to view the situation as the execution of a single event that is the join of the two events of eating a single apple. What these examples show is that it is always possible to describe a situation from two different perspectives. On the one hand, there is a set of events that corresponds to the changes that are brought about to a set of objects. On the other hand, there is only one event which is the join of the set of events. Event semantics, Krifka (1989, 1992), is based on the second perspective whereas the present framework is based on the first perspective. The advantage of proceeding from the set of events to their join is first that given the set of events it is always possible to recover the elements from which it is built up whereas this is not possible after the join has been constructed and second that the level of sets of events seems to be more appropriate for an analysis of aspectual phenomena.[4]

It is important to note that the distinction between distributivity and collectivity does not coincide with that between simultaneous and non-simultaneous (say, successive) executions. For instance, on the distributive reading of 'Five boys pushed three carts' each boy can have pushed his three carts either simultaneously or successively. Similarly, the boys can have pushed the carts either simultaneously or non-simultaneously. On the other hand, collectivity does not imply simultaneity. If four athlets are running in a 100m relay, they are running successively although the whole action is done collectively (a single athlet cannot run a 100m relay).

Whereas an argument NP restricts (or partly determines) the number of events and therefore the number of processes that must be executed, the verb v semantically determines the type of event (P_v) and, via the functions γ and δ, the type of sequential program (binary relation on S) of which the execution-sequences of (completed) events of this type must be an element. If the arguments are singular and non-mass, the aspectual properties of the expression are semantically determined by the properties the binary relation has that is fixed by γ and δ (see section (4.1) below). If the arguments are plural (or if an argument is plural), sets of events are denoted. The execution-sequences of sets of events can have properties that differ from those which the execution-sequences of their elements have. As a consequence, the aspectual properties of expressions with plural arguments can differ from those of expressions in which only singular, non-mass arguments occur. From this it does not follow that the properties that are determined by the verb do no longer matter if instead of a single event a set of events is denoted. Rather what one gets is the following principle (P).

(P) The aspectual properties of a verbal expression (projection of V, i.e. the verb in the lexicon corresponding to level 0) at level n are a function of the aspectual properties at all levels m with $0 \leq m \leq n$

For a transitive verb like 'eat' or 'push' there are two argument NPs such that both at the VP- and at the S-node sets of events are introduced. At each level the corresponding execution-sequences have certain properties. Similar to the execution-sequences of single events, the execution-sequences of sets of events can be characterized by invariance- and non-invariance properties. These properties are related to the interpretation of the argument NPs. From this it follows that at each level it is possible to get a kind of local durativity. Local durativity at level 0 (verbs in the lexicon) was already discussed above. It is explained in terms of the **G**-operator. Local durativity at higher levels (VP-, S-node) where sets of events are introduced will be explained in a similar manner. Local durativity at level n must be distinguished from global durativity at that level. Whereas local durativity only depends on the properties the execution-sequence of the event or set of events has at that level, global durativity also depends on the properties of the execution-sequences of events or sets of events that were introduced at lower levels. Furthermore, in order to

[4] These points are further developed in Naumann/Latrouite (1999) where Tagalog, the main dialect spoken in the Philippines, is analyzed in the present frameqork. In this analysis we assume that sentences like 'John pushed three carts' denote a single event e. To this single event several transformations of state correspond that are related to particular participants of the event. Each of these transitions can be interpreted as having been brought about by a subevent e' of e such that e is the join of the events e' that correspond to the transformations of states.

account for the difference in aspectual behaviour between bare and non-bare plural NPs two different kinds of invariance-properties must be distinguished.

contribution of	result	local durativity
verb	$\delta(P_v)(\rho(P_v)(e))\ (\phi_1)$	if $\gamma(P_v) = R_{\text{Con-BEC}}$, then $\tau(e) \models \mathbf{G}\phi_1\ [P_v, e]$
non-bare plural	?? (ϕ_2)	if ψ_2, then $\tau(E') \models \mathbf{G}\phi_2\ [E']$
bare plural	?? (ϕ_3)	if ψ_3, then $\tau(E') \models [R]\phi_3\ [E'']$

The following four questions must be answered: (i) What are the results indicated by ?? in the figure above (expressed by ϕ_2 and ϕ_3) brought about by sets of events (as opposed to the results that are brought about by their elements and that are determined by δ? (ii) Under what conditions ψ_2 and ψ_3 are ϕ_2 and ϕ_3 invariants? (iii) Under what conditions is a verbal expression at level n globally durative? (iv) What is the accessibility-relation R?

3 Aspectual Composition at the Plural Level

3.1 The Interpretation of Verbs in the Lexicon

There is the following (aspectual) asymmetry between the internal and the external argument of verbs like 'eat' or 'push': the change is effected with respect to (a property of) the object denoted by the internal argument and not with respect to (a property of) the denotation of the external argument. Furthermore, if the cardinality of the set W corresponding to the internal argument has cardinality n, each element $w \in W$ must be processed separately because for each element the result must be brought about. This fact can be expressed in terms of meaning postulates like $\forall e \forall W[e \in P_{eat} \wedge \theta_{PAT}(e) = W \rightarrow |W| = 1]$. Verbs for which such a meaning postulate holds will be called atomic with respect to the internal argument (or the θ_{PAT}-role).[5] The corresponding postulate does not hold for the external argument of verbs like 'eat' and 'push'. Two girls can share a pizza, i.e., there is one event e such that $\theta_{AG}(e) = \{g_1, g_2\}$. The observation about the internal arguments of 'eat' and 'push' cannot be generalized in the following way. Whenever the change expressed by a verb v is effected with respect to an argument-position P, v is atomic with respect to P (or with respect to the corresponding thematic role). A counterexample is given by the (intransitive) verb 'meet'. The change is effected with respect to the external argument. Yet, for the corresponding thematic role θ_{AG} one gets the postulate $\forall e \forall W[e \in P_{meet} \wedge \theta_{AG}(e) = W \rightarrow |W| > 1]$. It takes two to meet (cf. '*John met'). Thus, 'meet' is non-atomic with respect to its external argument. A consequence of what has been said above is that if the set W that is introduced or presupposed by an argument has cardinality n, i.e. if $|W| = n$, the verb need not necessarily be interpreted with respect to the set W but it can be interpreted with respect to subsets of W such that the union of these subsets is W. This fact must be accounted for in the interpretation of verbs

[5] This assumption is not essential for the theory that is developed in section (4). It is also possible to assume that a single event e is related to several objects with respect to which a change is effected. On this assumption it must be required that e's execution sequence is an element of $\gamma(P_v)(Q_i)$ for $1 \leq i \leq n$ and Q_i is the property of the i-th object that undergoes a change effected by e.

and NPs.

In the present framework (non-stative) n-place verbs are interpreted as $n+1$-ary relations. The additional argument is an event-argument that represents the dynamic component, i.e. that non-stative verbs express changes. The relationship between the 'ordinary' (subcategorized) arguments and the event-argument is captured by thematic roles (similar to the way this relationship is determined in event-semantics). In contrast to event-semantics the aspect of a change as a transformation of state is also represented by requiring that the execution-sequence $\tau(e)$ of e is an element of the binary relation that is determined by γ and δ for the event-type P_v that corresponds to the verb v. The discussion of the examples in section (2) has shown that the primary function of NPs is to 'spawn' sets of events (or processes) whereas the verb determines the type of the events. This difference will be accounted for in the present framework by assuming that the event-argument of a verb in the lexicon is required to denote singleton sets. Non-singleton sets of events are only introduced by NPs. The interpretation of 'eat' is given in (15a), that of 'push' in (15b) (Y,X are variables over sets of individuals, E' is variable over sets of events; $I = \lambda x \lambda y.x = y$ and the θ_{TR} are (partial) functions which map events (and sets of events) to sets of objects; for details see the appendix; e is the type of 'ordinary' objects, ε the type of events)

(15) a. $\lambda Y_{\langle e,t\rangle} \lambda X_{\langle e,t\rangle} \lambda E'_{\langle \varepsilon,t\rangle} \exists e[I(e) = E' \wedge e \in P_{eat} \wedge \theta_{AG}(e) = X \wedge \theta_{PAT}(e) = Y \wedge \tau(e) \in R_{Min-BEC}(\delta(P_{eat})(Y))]$ where $\gamma(P_{eat}) = R_{Min-BEC}$

b. $\lambda Y_{\langle e,t\rangle} \lambda X_{\langle e,t\rangle} \lambda E'_{\langle \varepsilon,t\rangle} \exists e[I(e) = E' \wedge e \in P_{push} \wedge \theta_{AG}(e) = X \wedge \theta_{PAT}(e) = Y \wedge \tau(e) \in R_{\text{Con-BEC}}(\delta(P_{push})(Y))]$ where $\gamma(P_{push}) = R_{\text{Con-BEC}}$

3.2 The Van der Does-Verkuyl Analysis of NPs

According to the analysis of NPs developed by Van der Does and Verkuyl (1991), an NP is syntactically of the form [[SPEC [DET]] N] (where SPEC = specifier, DET = determiner and N = noun). An NP like 'the three apples' is parsed as 'the$_{SPEC}$ three$_{DET}$ apples$_N$'. The specifier element can be empty as in 'three apples'. The interpretation of this empty specifier is given in (16a). In (16b) two restriction-functions are given. Finally, in (16c) the interpretation of the empty specifier for the first restriction-function is spelled out. (D is a variable of type <<e,t>, <<e,t>, t>>, $\mathbf{P}$, $\mathbf{Q}$ is a variable of type <<e,t>,t> and X, W are variables of type <e,t>, see Van der Does/Verkuyl (1991) for details).

(16) a. $\lambda D \lambda X \lambda \mathbf{P}.\exists W[W \subseteq X \wedge D(X)(W) \wedge \exists \mathbf{Q} ps W[\mathbf{Q} = \mathbf{P}|^i_X]]$

b. $|^1 := \lambda X \lambda \mathbf{Y}.\lambda Y \exists Z[\mathbf{Y}(Z) \wedge Y = Z \cap X]$

$|^2 := \lambda X \lambda \mathbf{Y}.[\mathbf{Y} \cap AT(X)]$

c. $\lambda D \lambda X \lambda P.\exists W[W \subseteq X \wedge D(X)(W) \wedge \exists \mathbf{Q} ps W[\mathbf{Q} = \lambda Y \exists Z[\mathbf{P}(Z) \wedge Y = Z \cap X]]]$

($AT = \lambda X.\lambda Y.Y \subseteq X \wedge |Y| = 1$). Semantically, SPEC is a determiner-lift which takes the 'old' determiner of type <<e,t>, <<e,t>, t>> and returns the 'lifted' variant of type <<e,t>, <<<e,t>, t>, t>> where the second part <<<e,t>, t>, t> corresponds to the type of NPs in the plural setting. According to (16a), the empty specifier introduces a set W which is a subset of the set X denoted by the head noun and which must satisfy the cardinality condition imposed by the old determiner D ($D(X)(W)$). In contrast to other interpretations of NPs this set need not itself be an argument of the verb. Rather there is a partition $\mathbf{Q}$ of W ($\mathbf{Q}psW$) such that each cell of this partition is a subset of a set that is an argument of the verb. (a partition $\mathbf{Q}$ of a set X is a set (of sets) such that (i) $\cup\mathbf{Q} = X$, (ii) for all Y,$Y' \in \mathbf{Q}$ with $Y \neq Y'$:$Y \cap Y' = \emptyset$ and (iii) $\emptyset \notin \mathbf{Q}$). This is expressed by $\exists\mathbf{Q}psW[\mathbf{Q} = \mathbf{P}|^i_X]$. The functions $|^i$ restrict a set (of sets) $\mathbf{Y}$ to a set X. In the particular application the denotion of (intransitive) verbs and VPs is restricted to the set that is denoted by the head noun. The function $|^2$ restricts $\mathbf{Y}$ to those elements that are singletons the element of which is an element of X. $|^1$ restricts the elements Y of $\mathbf{Y}$ to those subsets X' that are elements of X. Thus, whereas $|^2$ counts only singletons that are subsets of X, $|^1$ not only counts 'pure' subsets of X but rather each element of X that is an element of an element Y of $\mathbf{Y}$ such that also 'mixed' elements of $\mathbf{Y}$ are considered. If $\mathbf{P}|^1_X$ consists only of singletons, i.e., if $\mathbf{Q}$ is the finest partition of W, each element of W is subjected to the verb-denotation separately. This corresponds to a distributive reading. One gets a collective reading if $\mathbf{Q}$ is the coarsest partition, i.e., if it consists of only one cell which is the set W itself. Thus, it is only on a collective reading that W (possibly) is an element of the verb-denotation. Besides a distributive and a collective reading, the interpretation based on $|^1$ also admits so-called intermediate readings. For instance, 'Five boys pushed a cart' has a reading on which three boys pushed a cart together and the other two boys each pushed a cart on their own.

The identity $\mathbf{Q} = \mathbf{P}|^i_X$ consists of the two implications $\forall Y[Y \in \mathbf{Q} \rightarrow Y \in \mathbf{P}|^i_X]$ and $\forall Y[Y \in \mathbf{P}|^i_X \rightarrow Y \in \mathbf{Q}]$. The first implication says that each cell Y of the partition Q is also an element of the restriction of the verb-denotation. It does not exclude that there is a W' such that $W \subset W'$ and W' satisfies $\exists\mathbf{Q}'psW'\forall Y[Y \in \mathbf{Q}' \rightarrow Y \in \mathbf{P}|^i_X]$. Thus, if only the first implication were imposed, a sentence like 'John ate three apples' would be equivalent to 'John ate at least three apples'. Therefore, a maximality condition must be imposed which says that if a set (satisfying the relevant condition) is not an element of the partition, then it is not an element of the verb-denotation. This is done by the second implication of the identity. The function of the determiner D is to impose a quantificational condition on W: $D([\![N]\!])(W)$. For instance, if $D = \lambda X.\lambda Y.|X \cap Y| = 3$, this condition, together with the further condition $Y \subseteq X$ imposed by the specifier, yields $|W| = 3$. The set W must therefore satisfy two conditions: it must satisfy the quantificational condition imposed by the determiner and it must be the union of a set of sets which is the restriction of the verb-denotation to elements of the head-noun denotation $[\![N]\!]$. The interpretation of the head-noun, finally, restricts the set W sortally. This restriction is aspectually not relevant.

The advantage of the Van der Does/Verkuyl analysis of NPs is twofold. First, it admits to interpret a verb or a VP with respect to the elements of a partition of the set W corresponding to an argument and not necessarily with respect to W itself. Second, this analysis can easily be adjusted to interpret an NP as spawning a set of events where each event corresponds to a cell of the partition $\mathbf{Q}$ of the set W. The empty specifier is interpreted not only as introducing a set W but also a set of events E' that is the union of the sets of events which θ_{TR}-processed a cell of the partition of W (where θ_{TR} is the thematic role corresponding to the argument-position in which the NP occurs). In order to simplify matters in the discussion to follow two simplifying assumptions are made. First, no maximality condition is imposed and second it is assumed that the sets that are denoted by the subcategorized arguments are not 'mixed', i.e. do not have elements that belong to different N_{CN}. (D is a variable over determiner-denotations, **P** and **F** are variables over intransitive verb (or VP)-denotations).

(17) a. $SPEC_{\emptyset_D} = \lambda D \lambda X \lambda \mathbf{P} \lambda E' \exists W \exists \mathbf{F}[W \subseteq X \wedge D(X)(W) \wedge$
$\forall y[W(y) \rightarrow \exists E\text{"} \mathbf{P}(I(y))(E\text{"})] \wedge$
$\forall Z \forall E'' \forall E'''[\mathbf{F}(Z)(E'') \wedge \mathbf{F}(Z)(E''') \rightarrow E'' = E'''] \wedge$
$E' = \lambda e\text{"} \exists y \exists E\text{"}[e\text{"} \in E\text{"} \wedge W(y) \wedge \mathbf{F}(I(y))(E'') \wedge \mathbf{P}(I(y))(E\text{"})]]$

b. $SPEC_{\emptyset_N} = \lambda D \lambda X \lambda \mathbf{P} \lambda E' \exists W \exists \mathbf{F} \exists \mathbf{Q}[W \subseteq X \wedge D(X)(W) \wedge \mathbf{Q} psW \wedge$
$\forall Y[\mathbf{Q}(Y) \rightarrow \exists E\text{"} \mathbf{P}(Y)(E\text{"})] \wedge$
$\forall Z \forall E'' \forall E'''[\mathbf{F}(Z)(E'') \wedge \mathbf{F}(Z)(E''') \rightarrow E'' = E'''] \wedge$
$E' = \lambda e\text{"} \exists Y \exists E\text{"}[e\text{"} \in E\text{"} \wedge \mathbf{Q}(Y) \wedge \mathbf{F}(Y)(E'') \wedge \mathbf{P}(Y)(E\text{"})]]$

If a verb is atomic with respect to an argument-position, the distributive variant (17a) must be used. For non-atomic argument-positions the variant in (17b) can be used.

4 The Referential and the Quantificational Condition

The first question that has to be answered is what is the result (or are the results) that are brought about by a set of events as opposed to the results that are brought about by its elements. The empty specifier introduces a set W which is restricted by the determiner with respect to its cardinality: $D_{DET}(X)(W)$. From this requirement two conditions on the set E' that is introduced together with W can be inferred. Recall that each event e is related to an n-tuple of sets of objects by means of the thematic roles for which the event-type P_v to which it belongs is defined.

From this it follows that the union of the sets Y' that are related to an element e of E' by the thematic role θ_{TR} that corresponds to the argument-position in which E' is introduced must equal the set W that is introduced by the specifier. This yield the referential condition RC in (18).

(18) **Referential Condition (RC)**
the union of the sets Y' such that $\theta_{TR}(e) = Y'$ for some $e \in E'$ must equal W:
$W = \cup\{Y' \mid \exists e \in E': \theta_{TR}(e) = Y'\}$

The condition RC must be satisfied at the target-state of E', that is at the output-state of E''s execution-sequence and functions therefore as a result that is brought about by E'. The execution-sequence $\tau(E')$ of a set of events E' is defined as $\tau(E') = join(\Sigma)$ where $\Sigma = \{\sigma \in S^* \mid \exists e \in E' : \tau(e) = \sigma\}$. The execution-sequence of a (finite) set of events E' is the smallest sequence of which the execution-sequence of each element of E' is a subsequence.

Informally, RC can be paraphrased as 'the set W has been θ_{TR}-processed by E'.' Notice that RC is a global condition in the sense that it need not be satisfied by any element of E' separately nor by any proper subset of E'. It is therefore a condition that cannot be reduced to the results that are brought about by the elements of E'. RC is called the referential condition because it is formulated independently of how the set W is referred to, for instance by a bare plural or a non-bare plural. The second condition that E' must satisfy at its target-state, on the other hand, is not independent of the way W is referred to. It is directly formulated in terms of the condition that is imposed by the determiner.

(19) **Quantificational condition (QC)**
the union of the sets Y' such that $\theta_{TR}(e) = Y'$ for some $e \in E'$ must satisfy the cardinality-condition:
$D_{DET}(X)(Z)$, where $X = [\![N]\!]$ and $Z = \cup\{Y' \mid \exists e \in E'\colon \theta_{TR}(e) = Y'\}$

One may argue that given $D_{DET}(X)(W)$ RC and QC are equivalent and are therefore a single condition that E' must satisfy. This is not true. First, in contrast to the referential condition RC, QC is not formulated in terms of the set W. Furthermore, below it will be shown that aspectually RC and QC give rise to two different kinds of invariance-properties that are not equivalent to each other such that RC and QC cannot be identified.

4.1 The Referential Condition

The crucial question that must be answered is under what conditions does RC correspond to an invariant of the execution-sequence of E'. In order to answer this question it must first be specified what it means that a set Y' is θ_{TR}-processed by an event e at a state s.

(20) $proc(Y', \theta_{TR}, e, s)$ iff $s \in \tau'(e) \wedge \theta_{TR}(e) = Y'$

According to (20), a set Y' is θ_{TR}-processed at a state s by an event e just in case Y' is the value of θ_{TR} for e and s is an element of the maximal suffix of e's execution-sequence $\tau'(e)$. ($\tau'(e) = \tau(e) - \{\alpha(e)\}$). (20) is based on the assumption that non-stative verbs express changes. Each event $e \in P_v$ is related to an n-tuple of (sets of) objects by means of the thematic roles for which P_v is defined. These objects are processed by e immediately after it has been started, i.e. as soon as some change (transformation of state) is brought about. Recall from section (1) that for expressions with non-bare plural NPs like 'three apples' or 'five carts' modification with a *for*-adverbial is possible only if the events are executed simultaneously. Thus, one has to distinguish two principle cases: (a) all elements of E' are started simultaneously or (b) not all elements of E' are started simultaneously. In the first case RC is an invariant of the execution-sequence $\tau(E')$ of E' (if it is satisfied at all). This follows from the fact that if each element e of E' is started at the same state s, the union of the sets Y' that are θ_{TR}-processed by the elements of E' equals W for all states of the execution-sequence of E' except its source-state (which is s, according to the definition of $\tau(E)$). In (21) three parametrized functions are defined that admit to calculate how the RC is evaluated on the execution-sequence $\tau(E')$ of E'.

(21) a. $G_{E',\theta_{TR}} : \tau(E') \rightarrow \wp(O)$
$G_{E',\theta_{TR}}(s) = Y^*$ and $Y^* = \cup\{Y' \mid \exists e \in E'\colon \theta_{TR}(e) = Y' \wedge s \in \tau'(e)\}$
b. $G'_{E',\theta_{TR}} : prefix(\tau(E')) \rightarrow \wp(O)$
$G'_{E',\theta_{TR}}(\langle s_0\rangle) = \emptyset$
$G'_{E',\theta_{TR}}(\langle s_0, ..., s_j\rangle) = G'_{E',\theta_{TR}}(\langle s_0, ..., s_{j-1}\rangle) \cup G_{E',\theta_{TR}}(s_j)$
c. $G''_{E',\theta_{TR},W} : \tau(E') \rightarrow 2$
$G''_{E',\theta_{TR},W}(s) = 1$ iff $G'_{E',\theta_{TR}}(\langle s_0, ..., s_j\rangle) = W$ and $s_j = s$

As sequences of states are convex subsets of S, the set of prefixes of $\tau(E')$ can be defined as the set of non-empty convex subsets of $\tau(E')$: $prefix(\sigma) = \Sigma$ iff $\Sigma =$

$\{\sigma' \in S^* \mid \sigma' \subseteq \sigma \wedge convex(\sigma') \wedge \sigma' \neq \emptyset\}$. The function $G_{E',\theta_{TR}}$ assigns to each state $s \in \tau(E')$ the union of the sets Y' that are θ_{TR}-processed by an element e of E' at s. The function $G'_{E',\theta_{TR}}$ assigns to each prefix of $\tau(E')$ the union of the values for $G_{E',\theta_{TR}}$ of all s that are elements of that prefix. Thus, $G'_{E',\theta_{TR}}$ calculates for each $s \in \tau(E')$ the union of the values of θ_{TR} for the elements e of E' that have been θ_{TR}-processed up to s. The function $G''_{E',\theta_{TR},W}$ finally maps each state $s \in \tau(E')$ to 1 just in case the value of $G'_{E',\theta_{TR}}$ for the sequence with s as last state is W. For instance, if John ate three apples one after the other such that the sequences $\langle s, s_1\rangle$, $\langle s_1, s_2\rangle$ and $\langle s_2, s'\rangle$ are the sequences on which the three apples were eaten, respectively, $G'_{E',\theta_{PAT}}$ yields the value $\{a_1\}$ for all elements of $\langle s, s_1\rangle$ except for s. The value for $G''_{E',\theta_{PAT}}$ is $\{a_1\}$ for all prefixes $\langle s, s_n\rangle$ of $\langle s, s'\rangle$ with $s < s_n \leq s_1$, $\{a_1, a_2\}$ for all prefixes $\langle s, s_n\rangle$ with $s_1 < s_n \leq s_2$ and $\{a_1, a_2, a_3\}$ for all prefixes $\langle s, s_n\rangle$ with $s_2 < s_n \leq s'$.

If $G''_{E',\theta_{TR},W}(s) = 1$ for all $s \in \tau^*(E')$, RC is an invariant of the execution-sequence in the sense that it is true at the culmination-point CP and at all states of the development-portion DP. Let $\phi_2\ [E', \theta_{TR}, W]$ express the parametrized property of states that is defined by $G''_{E',\theta_{TR},W}$, i.e., $\tau(E'), k \models \phi_2\ [E', \theta_{TR}, W]$ iff $G''_{E',\theta_{TR},W}(s_k) = 1$. In case $G''_{E',\theta_{TR},W}$ maps all elements of $\tau'(E')$ to 1, (P2) holds.

(P2) $\tau(E') \models \mathbf{G}\phi_2\ [E', \theta_{TR}, W]$

(P2) corresponds to a constant role in event semantics, Eberle (1996), Krifka (1989, 1992). The semantic function of the $G^i_{E',\theta_{TR}}$ can therefore be interpreted as defining a structural relationship between $\wp(E)$ and $\wp(O)$. The execution sequence of a set of events E' can either be constant or non-constant with respect to a set W of objects to which E' is θ_{TR}-related. The execution sequence is constant with respect to W if all elements of W are processed simultaneously, otherwise it is non-constant. The constant character is expressed by (P2). In terms of properties of execution sequences this means that the condition that expresses the RC is an invariant of the execution-sequence. Non-constancy corresponds to a kind of graduality in the sense this notion is defined in event semantics. The set W is θ_{TR}-processed in such a way that there are intermediate states of the execution sequence at which only a proper subset of W is θ_{TR}-processed. This form of graduality is weaker than the one that is usually assumed in event semantics because it is not required that the set W is completely θ_{TR}-processed only at the target-state of E''s execution-sequence.

Local durativity with respect to the RC at level $n > 0$ is defined in terms of (P2).

(22) a verbal expression is locally durative w.r.t. RC at level $n > 0$ iff (P2) holds for all events E' that are introduced (or presupposed) at that level, that is $\tau(E') \models \mathbf{G}\phi_2\ [E', \theta_{TR}, W]$ holds for all events E' with respect to the thematic role θ_{TR} that corresponds to level n and W is the set corresponding to E'.

Definition (22) faces the following problem. Consider 'John pushed two carts in ten minutes'. This sentence may be true if John pushed the same cart twice. In such a situation $G''_{E',\theta_{TR},W}$ yields the value 1 for all non-initial states of $\tau(E')$ such that only modification with a *for*-adverbial should be possible. This problem can be solved as follows. Instead of only defining a function $G''_{E',\theta_{TR},W}$ that calculates for each $s \in \tau(E')$ whether the set of objects already θ_{TR}- processed equals W, one in addition defines a (parametrized) function $F_{E'}$ from $\tau(E')$ to 2 that maps an element $s \in \tau(E')$ to 1 just in case the set of elements from E' that have already begun or that have already terminated equals E'. $F_{E'}$ can be defined as follows: $F_{E'}(s) = 1$ iff $E' = \{e \in E \mid e \in E' \wedge \alpha(e) < s\}$. In contrast to $G''_{E',\theta_{TR},W}$ $F_{E'}$ is not an invariant of $\tau(E')$. If local durativity w.r.t. RC at level n is defined in terms of $F_{E'}$ rather than in terms of $G''_{E',\theta_{TR},W}$ no problem arises.

The necessity to speak of all events that are introduced or presupposed at level n is best explained by means of the following example. Consider the VP 'push three carts'. At the V-node one gets three events e_1, e_2 and e_3 that are all of type pushing (i.e. $e_i \in P_{push}$, $1 \leq i \leq 3$). To the next higher node, the VP-node, there corresponds a set of events E' the elements of which are the three events at the V-node. At each node the corresponding event(s) must satisfy a particular condition that functions as the result at the level corresponding to the node. Each event e_i at the V-node must bring about the result that is determined by δ in the way determined by γ for P_{push}: $\tau(e_i) \in \gamma(P_{push})(\delta(P_{push})(\rho(P_{push})(e_i)))$. For the events e_i of type pushing this means that the carts c_i traverse a non-empty path. At the VP-node the event E' must satisfy the referential condition RC at its target-state. If the three carts are c_1, c_2 and c_3, this yields (23).

(23) $\{c_1, c_2, c_3\} = W = \cup\{Y' \mid \exists e \in E' : \theta_{PAT}(e) = Y'\}$

As each cart must be pushed separately, this means that the Y' are singletons: $\{c_1, c_2, c_3\} = W = \cup\{\{c_1\}, \{c_2\}, \{c_3\}\}$. The condition at the VP-node is a condition that the elements of E' must satisfy collectively.

For the sentence (-radical) 'five boys push three carts' on its distributive reading, one gets the following analysis. At the S-node a set E' of fifteen events is introduced. Each element is the pushing of one cart by one of the five boys. At the VP-node one gets five (sets of) events E_i, $1 \leq i \leq 5$, each consisting of three events e_{ij}, $1 \leq j \leq 3$. The event E' at the S-node is the union of the E_i : $E' = \cup E_i$. Finally, at the V-node one gets fifteen events e_{ij}, $1 \leq i \leq 5$, $1 \leq j \leq 3$. The result brought about by each e_{ij} is the same as that in the case of the VP 'push three carts': the cart that is related to e_{ij} must traverse a non-empty path. The E_i must satisfy the referential condition RC which yields (24).

(24) $\{c_{i1}, c_{i2}, c_{i3}\} = W = \cup\{Y' \mid \exists e_{ij} \in E_i\colon \theta_{PAT}(e_{ij}) = Y'\}$

At the S-node the corresponding event E' too must satisfy the referential condition RC.

(25) $\{b_1, b_2, b_3, b_4, b_5\} = Z = \cup\{Z' \mid \exists e_{ij} \in E' : \theta_{AG}(e_{ij}) = Z'\}$

In the example each Z' is a singleton (because a distributive reading is assumed) such that $Z = \cup\{\{b_1\}, \{b_2\}, \{b_3\}, \{b_4\}, \{b_5\}\}$. The example has shown that global durativity at level n requires local durativity at each level $m \leq n$ for each E' that is introduced at level m with $1 \leq m \leq n$ and for each event e at level 0. One therefore arrives at the definition of global durativity with respect to RC at level n in (26).

(26) **Global Durativity with respect to RC at level n**

A verbal expression at level n with underlying verb v is globally durative with respect to RC iff

(i) (P1) does hold at level 0 (V^0)

(P1) $\forall e \in P_v : \tau(e) \models \mathbf{G}\phi_1\ [P_v, e]$ and

(ii) (P2) does hold for the execution-sequence $\tau(E')$ of each event E' that is introduced at some level m s.t. $0 < m \leq n$
(P2) $\tau(E') \models \mathbf{G}\phi_2\ [E', \theta_{TR}, W]$
where θ_{TR} is the thematic relation corresponding to level m and W is the set that corresponds to E'

If no bare plural occurs in an expression, modification with a *for*-adverbial at level n is possible only if the expression at that level is globally durative with respect to RC. According to the above definition, a verbal expression at level n is globally durative with respect to RC just in case it is locally durative w.r.t. RC at all levels m with $1 \leq m \leq n$ and locally durative at level 0. The following examples show that this definition is confirmed by the data.

(27) eat simultaneously two apples in ten minutes/*for ten minutes

The condition that each apple is being processed is invariantly satisfied, i.e., (P2) holds for the set of events E' introduced at the VP-node such that one gets local durativity with respect to RC at level 1: $E' = \{e_1, e_2\}$: $\tau(E') \models \mathbf{G}\phi_2\ [E', \theta_{TR}, W]$. What is not satisfied is (P1) at level 0 (V-node). The event-type P_{eat} is assigned the Min-BEC mode: $\gamma(P_{eat}) = R_{Min-BEC}$ such that there is no local durativity w.r.t. RC at level 0.

(28) push two carts successively in ten minutes/*for ten minutes

In this case one gets local durativity w.r.t. RC at level 0 because P_{push} is assigned the Con-BEC mode such that (P1) holds. As the execution of the two events at level 0 is assumed to be non-simultaneous, one does not get local durativity w.r.t. RC at level 1 because the referential condition is not invariantly satisfied on the execution-sequence $\tau(E')$ of E'.

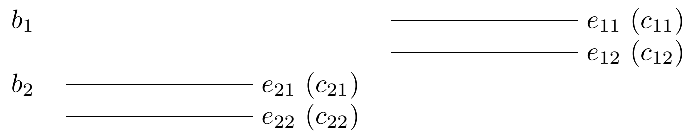
From these examples the following consequences can be drawn. First, if the underlying verb v corresponds to an event-type P_v such that $\gamma(P_v) = R_{Min-BEC}$, the expression is locally non-durative with respect to RC. Local durativity w.r.t. RC at level 0 is sufficient for global non-durativity w.r.t. RC at all higher levels. In this case it does not matter in which temporal order the events are executed. For instance, whether the two apples are eaten simultaneously or non-simultaneously has no influence on the aspectual properties of the expression. This observation can be generalized in the following way.

R1 Local non-durativity w.r.t. RC at one level $m \leq n$ is sufficient for global non-durativity w.r.t. RC at level n.

If no bare plural occurs in an argument-position such that the expression is not globally durative w.r.t. QC, R1 can be strengthened to R2.

R2 If a verbal expression is not globally durative w.r.t. QC at level n, local non-durativity w.r.t. RC at one level $m \leq n$ is sufficient for global non-durativity at level n.

Even if an expression is globally durative w.r.t. RC at level n, it can be globally non-durative at level $n + 1$ if it is locally non-durative w.r.t. RC at level $n + 1$. An example is given by 'Two boys pushed two carts' on the reading that can be paraphrased by 'Successively, two boys pushed two carts simultaneously'. This VP is locally durative w.r.t. RC both at level 0 ($\gamma(P_{push}) = R_{\text{Con-BEC}}$) and at level 1 (simultaneous execution). As the two boys are supposed to have pushed their carts not together, one gets local non-durativity w.r.t. RC at the S-node. Below a possible execution-sequence is given.



One gets local durativity w.r.t. RC at level 0 (V-node) because $\gamma(P_{push}) = R_{\text{Con-BEC}}$ and local durativity w.r.t. RC at level 1 (VP-node): there are two sets E_1 and E_2 both consisting of two events: $\tau(E_i) \models \mathbf{G}\phi_2\ [E_i, \theta_{PAT}, W_i]$. Level 2 (S-node) is not locally durative w.r.t. RC: $E' = \cup E_i : \tau(E') \not\models \mathbf{G}\phi_2\ [E', \theta_{AG}, W]$.

The referential condition RC applies to all types of NPs, singular and plural ones, either bare or non-bare. Singular, non-mass NPs can never give rise to local non-durativity w.r.t. RC. In this case E' is a singleton such that (P2) always holds for the execution-sequence of E'. If there is only one event, the referential condition is invariantly satisfied because there can be no temporal succession with respect to the set W of objects that is θ_{TR}-related to the event e such that $E' = I(e)$. From this it follows that for an (unmodified) expression with only singular, non-mass arguments the aspectual behaviour is completely determined by the functions γ and δ (for the event-type P_v corresponding to the underlying verb v). This explains why in section (1) it was not necessary to distinguish between the contribution of a verb and those of singular, non-mass NPs. A VP like 'push a cart' where the event-type P_v corresponding to the verb is assigned the Con-BEC mode and the (internal) argument is singular and non-mass can therefore only be modified by a *for*-adverbial and not by an *in*-adverbial because it is globally durative w.r.t. RC which is sufficient for global durativity.Both (P1) and (P2) hold for each execution-sequence. (P1) holds because 'push' is an activity-verb: $\gamma(P_{push}) = R_{\text{Con-BEC}}$. (P2) holds because if $|W| = 1$, no proper spawning of events or processes can take place in the sense that at least two events (processes) are executed. Both for a distributive and a collective reading one gets only one event. Yet, the spawning of processes (events) is a necessary condition for global non-durativity w.r.t. RC if $\gamma(P_v) = R_{\text{Con-BEC}}$. On the other hand, a bare plural NP can give rise to local non-durativity w.r.t. RC at level n. If the events are executed non-simultaneously, this yields local non-durativity w.r.t. RC at level n (if the bare plural occurs in the corresponding argument-position), i.e., (P2) does not hold for the execution-sequence $\tau(E')$ of the corresponding set of events E'. Thus 'push carts' as well as 'eat apples' can be globally non-durative w.r.t. RC at the VP-level (the latter is always globally non-durative w.r.t. RC because 'eat' is an accomplishment-verb). They are not globally non-durative because a bare plural always leads to local durativity w.r.t. QC which is sufficient for global durativity at that level and an expression is globally non-durative at level n just in case it is neither globally durative w.r.t. RC at level n nor globally durative w.r.t. QC at level n (see below section (4.2)).

Modification of an expression with a *for*-adverbial only requires that the expression is globally durative w.r.t. RC at that level to which the modification applies. Consider again the example 'Five boys pushed three carts' according to the reading 'Successively, five boys pushed three carts simultaneously'. As was shown above, this sentence is not globally durative at the S-node (level 2) because it is locally non-durative at that node. On the other hand, the sentence is globally durative at the VP-node (level 1) because (P2) does hold for each set of events E_i, $1 \leq i \leq 5$, that is introduced at that level and (P1) holds at level 0 (V^0-node) because $\gamma(P_{push}) = R_{\text{Con-BEC}}$. From this it follows that modification of 'Five boys pushed three carts with the for-adverbial 'for twenty minutes' is possible (yielding 'Five boys pushed three carts for twenty minutes') although the sentence is not globally durative at the S-node. The meaning of this sentence is that each of the five boys pushed his three carts together for twenty minutes and that the five boys did their pushings successively.

4.2 The Quantificational Condition

The specific contribution of bare plural NPs that distinguishes them from non-bare plural NPs will be explained with respect to the quantificational condition, repeated below for convenience.

(19) **Quantificational Condition (QC)**
The union Z of the sets Y' that are θ_{TR}-processed by the elements of E' must satisfy the cardinality condition
$D_{DET}(X)(Z)$, with $X = [\![N]\!]$ and $Z = \cup\{Y' \mid \exists e \in E' \colon \theta_{TR}(e) = Y'\}$.

Similar to the case of the referential condition RC, the above thesis must not be misunderstood in the sense that the QC applies only to bare plural NPs and not to other types of NPs. Rather, it applies to all types of NPs. But bare plural NPs satisfy this condition in such a way that distinguishes them from all other types of NPs.

I will follow Krifka in interpreting the bare determiner by an existential quantification over the cardinality.

(29) $D_{bare} = \lambda X \lambda.Y.\exists n|X \cap Y| = n$

According to (29), D_{bare} is the only determiner that does not exclude any cardinality and therefore does not exclude any set from $\wp^*([\![N]\!])$ (where $X = [\![N]\!]$). The following two determiners may be possible counterexamples to this claim: 'at least one' and 'some', if they are interpreted as $D_{at\_least\_1} = \lambda X.\lambda Y.|X \cap Y| \geq 1$ and $D_{some} = \lambda X.\lambda Y.\exists n|X \cap Y| = n$, respectively. Yet for 'some' in its plural use ('some apples') the interpretation $\lambda X.\lambda Y.|X \cap Y| \geq 2$ is more appropriate that does exclude the cardinality 1. For 'at least one' also material parts of objects have to be considered such that cardinalities less than 1 are excluded that are not excluded by a bare plural witness examples like 'Did you eat apples?', 'Yes, I ate half an apple'.[6]

[6] This idea can be made more precise as follows. Consider the sentence 'John ate half an apple'. If this sentence is true, there is a single object that John ate, i.e., the cardinality of the set introduced by the interpretation of the internal argument NP is 1. There therefore is no difference with respect to the cardinality in this case and that in the case where John ate an apple. In both cases the set that is introduced has cardinality 1. What these two examples show is that, in effect, one has to distinguish between two different types of cardinality information. On the one hand there is the proper cardinality information that is usually associated with the interpretation of a determiner. On the other hand, there is what will be called the natural unit that is assigned to the join of the

How can this difference be applied to the present framework? Similar to the RC the quantificational condition QC functions as a result that must be brought about by a set of events E'. Recall that SPEC semantically spawns a set of events (or processes). This set can possibly be restricted by the condition imposed on the set W by the determiner because $W \in D_{DET}([\![N]\!])$ must hold. What does it mean that the determiner restricts E'? The referential condition RC requires that the set $\cup\{Y \mid \exists e \in E'\colon \theta_{TR}(e) = Y\}$ equals the set W, that is, the union of the sets Y that are θ_{TR}-processed by the elements e of E' equals the set W that is introduced or presupposed at the argument-position at which E' is introduced. This is a simple consequence of the referential character of the RC. The question of whether besides $\cup\{Y \mid \exists e \in E'\colon \theta_{TR}(e) = Y\}$ other sets, for instance sets that are θ_{TR}-processed by sub- or supersets of E', satisfiy this condition does not make sense because there is exactly one set that can satisfy this condition, namely the set W. For the quantificational condition, on the other hand, the question of whether for a given set E' that satisfies the QC this condition is also satisfied for sub- and supersets E'' is meaningful because the QC is a pure quantificational condition that is independent of the particular set W that is introduced or presupposed. Thus, one can ask the following questions. Suppose E' satisfies QC, does

(i) each (non-empty) subset E'' of E' satisfy QC?

(ii) each superset E'' (such that each element of E'' is defined for θ_{TR}) satisfy the QC?

If $D_{DET} = D_{bare}$, both (i) and (ii) are satisfied. This follows from the fact that D_{bare}, together with the requirement $W \subseteq [\![N]\!]$, only requires that there is an n such that $|W| = n$ This condition is satisfied for non-empty subsets E'' of E' and supersets E'' of E' because for non-empty subsets E'' the number of objects θ_{TR}-processed can at most be that of E': $\theta_{TR}(E') = W \wedge \theta_{TR}(E'') = W' \wedge E'' \subseteq E' \rightarrow W' \subseteq W$. For supersets E'' of E', on the other hand, the number of objects θ_{TR}-processed must at least be that of E': $\theta_{TR}(E') = W \wedge \theta_{TR}(E'') = W' \wedge E' \subseteq E'' => W \subseteq W'$. Yet, the conditions (i) and (ii) can also be satisfied if $D_{DET} \neq D_{bare}$. An example is given by 'More than five boys ate two pizzas' on its collective reading where the boys shared two pizzas. In this case the set E' at the S-node consists of two elements. Condition

elements of the set that is introduced (or presupposed) by the interpretation of an NP (compare the function 'num' that is used in Krifka, 1989). Although the proper cardinality n can be identical, the natural unit that is determined can be different. An example is given by 'an apple' vs. 'half an apple'. In both cases $n = 1$. But in the former $m = 1$, whereas in the latter $m = 0.5$. A determiner directly imposes a condition on the proper cardinality. The condition on the value of the natural unit is imposed indirectly. First, the value of the natural unit must always be less than or equal to the cardinality. In many cases it can be assumed that the two values have to be equal, e.g. for numerical determiners like 'one' or 'two', i.e., the quantificational condition determines the same value for both types of cardinality information. From this it follows that 'at least one' imposes both a condition on the cardinality and on the value of the natural unit: they are required to be greater than or equal to one. For instance, 'John ate at least one apple' is false in a situation where he ate only half an apple. The situation is different for a bare plural. In this case the value is existentially quantified. For the cardinality this means that it can be any value from the set of positive natural numbers (i.e., 0 is excluded). The value of the natural unit of the join of the elements of a set can be an element from a larger set, namely the set $\{x \mid x > 0\}$, i.e., values in between 0 and 1 are possible too (It will be assumed that x has to be an integer). For the value of the natural unit the existential quantification therefore has the effect that its value can be any element from $\{x \mid x > 0\}$, i.e., the value of the natural unit is not restricted, similary to the value of the cardinality. This is different for 'at least one' which excludes values less than 1 for the natural unit. Consequently, in contrast to 'at least one' a bare plural does *not* impose any restriction on the value of the natural unit. They agree on the condition that is imposed on the cardinality. On this analysis, the quantificational condition must be formulated not solely in terms of the cardinality condition imposed on the set W by the determiner, but rather in terms of both the cardinality condition and the condition imposed on the value of the natural unit. On this definition, a bare plural is the only determiner that restricts neither the value of the cardinality nor the value of the natural unit.

(i) is satisfied because for any non-empty subset of E' each pizza was eaten by the set of boys such that $\theta_{AG}(e_i) = B$, where B is the set of boys and e_i for $1 \leq i \leq 2$ is one of the two elements of E'. Condition (ii) is satisfied too because if $|B| > 5$, then $| \cup \{W' \mid \exists e \in E''\colon \theta_{AG}(e) = W'\}| > 5$ for any superset E'' of E' such that θ_{AG} is defined for each element of E''. Consequently, an attempt to distinguish bare plurals from other NPs by the conditions (i) and (ii) at the level of single events will not be successful. These conditions must rather be formulated at the level of event-types. The counterexample of the collective reading of 'More than five boys ate two pizzas' only shows that there are executions such that the event E' the union of objects that are θ_{TR}-processed by the elements of E' satisfies the QC. But this will not be true if one considers instead the event-type that consists of all events E' the elements of which are θ_{TR}-related to (a set of) objects such that the union of these sets satisfies the QC determined by D_{DET} with respect to some N_{CN}. This event-type is defined in (30c).

(30) a. $[e]_{\theta_{TR},N_{CN}} = \{e \in E \mid \exists Y[\theta_{TR}(e) = Y \wedge Y \subseteq N_{CN}]\}$
b. $[E']_{\theta_{TR},N_{CN}} = \{E' \subseteq E \mid E' \subseteq [e]_{\theta_{TR},N_{CN}} \wedge E' \neq \emptyset\}$
c. $[E']_{D_{DET},\theta_{TR},N_{CN}} = \{E' \subseteq E \mid E' \in [E']_{\theta_{TR},N_{CN}} \wedge D_{DET}(N_{CN})(\theta_{TR}(E'))\}$
d. $\theta_{TR}(E') = Y$ iff $Y = \cup\{Y' \mid \exists e \in E'\colon \theta_{TR}(e) = Y'\}$

$[E']_{\theta_{TR},N_{CN}}$ is the largest set (of sets of events) such that each element of an element of this set is θ_{TR}-related to a (non-empty) subset of N_{CN}. For instance, $[E']_{\theta_{PAT},N_{MAN}}$ is the set of sets of events such that each event that is an element of an element of this set is θ_{PAT}-related to a set of men. $[E']_{D_{DET},\theta_{TR},N_{CN}}$ is that subset of $[E']_{\theta_{TR},N_{CN}}$ such that each element is θ_{TR}-related to a subset of N_{CN} that satisfies a particular cardinality condition given by D_{DET}. If $DET = Three$, $[E']_{D_{Three},\theta_{PAT},N_{MAN}}$ is the set of subsets of E such that each element of this set is θ_{PAT}-related to a set of three men. The transition from $[E']_{\theta_{TR},N_{CN}}$ to $[E']_{D_{DET},\theta_{TR},N_{CN}}$ can be interpreted as the imposition of a postcondition (result). For $DET = bare$, $[E']_{D_{DET},\theta_{TR},N_{CN}} = [E']_{\theta_{TR},N_{CN}}$. This follows from the fact that D_{bare} does not exclude any cardinality. This shows that the condition $D_{bare}(N_{CN})(\theta_{TR}(E'))$ does not restrict the set $[E']_{\theta_{TR},N_{CN}}$. Each $[E']_{\theta_{TR},N_{CN}}$ and each $[E']_{D_{DET},\theta_{TR},N_{CN}}$ induces the relation on S^* defined in (31a) and (31b), respectively.

(31) a. $R_{[E']_{\theta_{TR},N_{CN}}} = \{\Sigma \subseteq S^* \mid \exists E' \in [E']_{\theta_{TR},N_{CN}}\colon \Sigma = \tau^*(E')\}$
b. $R_{[E']_{D_{DET},\theta_{TR},N_{CN}}} = \{\Sigma \subseteq S^* \mid \exists E' \in [E']_{D_{DET},\theta_{TR},N_{CN}}\colon \Sigma = \tau^*(E')\}$
c. $\tau^*(E') = \{\sigma \in S^* \mid \exists e \in E'\colon \sigma = \tau(e)\}$

$R_{[E']_{\theta_{TR},N_{CN}}}$ and $R_{[E']_{D_{DET},\theta_{TR},N_{CN}}}$ correspond to concurrent (or parallel) programs, i.e. to relations on $\wp(S) \times \wp(S)$. The property that characterizes bare plural NPs in contrast to other NPs is (P3) defined below.

(P3) $\forall E' \in [E']_{D_{DET},\theta_{TR},N_{CN}} \forall E'' \forall E'''$
(i) $E'' \subseteq E' \wedge E'' \neq \emptyset \rightarrow E'' \in [E']_{D_{DET},\theta_{TR},N_{CN}}$ and
(ii) $E' \subseteq E''' \wedge E''' \in [E']_{\theta_{TR},N_{CN}} \rightarrow E''' \in [E']_{D_{DET},\theta_{TR},N_{CN}}$

(P3) only holds for D_{bare} and for no other D_{DET} with $DET \neq bare$. For instance, although there are sets of events $E' \in [E']_{D_{more\_than\_n},\theta_{TR},N_{CN}}$ that satisfy (P3), there are equally sets of events for which (P3) fails to hold ((P3) can hold for $DET \neq bare$

in models that are not sufficiently rich in the sense that only particular types of executions occur, e.g. only collective ones. In this case (P3) must be formulated with respect to all models).

What is the aspectual impact of (P3)? Recall from section (2) that modifiability with a *for*-adverbial is to be explained by durativity at different levels. In the lexicon a verb v is durative if the execution sequences of events denoted by v satisfy (P1): $\forall e \in P_v : \tau(e) \models \mathbf{G}\phi_1\ [P_v, e]$, where ϕ_1 expresses the result that e must bring about. (P1) is satisfied only if the dynamic mode assigned to P_v is $R_{\text{Con-BEC}}$. If (P1) is satisfied, it follows that each (non-minimal) initial stage e' of e satisfies (P1) too. This can be expressed by (32a) where $Q = \delta(P_v)(\rho(P_v)(e))$. On the other hand, if $\gamma(P_v) = R_{\text{Con-BEC}}$, it follows that if two events e and e' of this type are executed one after the other such that they agree with respect to the objects they are related to by a thematic relation θ_{TR}, the result Q is not only satisfied upon termination of e but also upon termination of the sequential composition of e and e', (32b).

(32) a. $\forall e, e'[e \in P_v \wedge \text{initial-stage}(e', e) \wedge \tau(e) \in R_{\text{Con-BEC}}(Q) \rightarrow \tau(e') \in R_{\text{Con-BEC}}(Q)]$
b. $\forall e, e'[e \in P_v \wedge e' \in P_v \wedge \beta(e) = \alpha(e') \wedge \forall\theta\forall Y[\theta(e) = Y \longleftrightarrow \theta(e') = Y] \wedge \tau(e) \in R_{\text{Con-BEC}}(Q) \rightarrow \tau(e \cdot_E e') \in R_{\text{Con-BEC}}(Q)]$[7]

The procedural interpretation of (32) is that after an arbitrary number $n > 0$ of events of type P_v have been sequentially executed such that each event in the sequence is assigned the same result Q by δ Q is satisfied. Thus, (32) corresponds to the property of homogeneity used in event semantics. (P3) expresses the same property at the level of sets of events with respect to the QC. If $[E']_{D_{DET},\theta_{TR},N_{CN}}$ satisfies the closure-conditions in (P3), this means that after an arbitrary (non-empty) number of events $e \in [e]_{\theta_{TR},N_{CN}}$ have been executed, QC is satisfied at the target-state of the corresponding set E' of events, that is, at the target-state of $\tau(E')$.

At the level of the corresponding relation $R_{[E']_{D_{DET},\theta_{TR},N_{CN}}}$ defined in (31b) above, one gets the closure-conditions (33).

(33) a. $\Sigma \in R_{[E']_{D_{DET},\theta_{TR},N_{CN}}} \wedge \Sigma' \subseteq \Sigma \wedge \Sigma' \neq \emptyset \rightarrow \Sigma' \in R_{[E']_{D_{DET},\theta_{TR},N_{CN}}}$
b. $\Sigma \in R_{[E']_{D_{DET},\theta_{TR},N_{CN}}} \wedge \Sigma \subseteq \Sigma' \wedge \Sigma' \in R_{[E']_{\theta_{TR},N_{CN}}} \rightarrow \Sigma' \in R_{[E']_{D_{DET},\theta_{TR},N_{CN}}}$

Similar to (P1) and (P2), (P3) can also be formulated at the level of the execution-sequences of elements from $[E']_{D_{DET},\theta_{TR},N_{CN}}$.

(34) a. $\forall E' \in [E']_{D_{DET},\theta_{TR},N_{CN}} : \tau^*(E') \models \updownarrow \phi_3\ [D_{DET}, E', \theta_{TR}, N_{CN}]$
b. $\tau^*(E') \models \downarrow \phi_3[D_{DET}, E', \theta_{TR}, N_{CN}]$ iff for all E'' with $E'' \subseteq E'$ and $E'' \neq \emptyset, \tau^*(E'') \models \phi_3\ [D_{DET}, E'', \theta_{TR}, N_{CN}]$
c. $\tau^*(E') \models \uparrow \phi_3\ [D_{DET}, E', \theta_{TR}, N_{CN}]$ iff for all E'' with $E' \subseteq E''$ and $E'' \in [E']_{\theta_{TR},N_{CN}}, \tau^*(E'') \models \phi_3\ [D_{DET}, E'', \theta_{TR}, N_{CN}]$
d. $\Sigma \models \updownarrow \phi$ iff $\Sigma \models \uparrow \phi$ and $\Sigma \models \downarrow \phi$
e. $\Sigma \models \phi$ iff $join(\Sigma) \models R\phi$ (where ϕ does not contain any modal operators, i.e., ϕ is a state-formula)
f. $\sigma \models R\phi$ iff $\sigma, n \models \phi$ where n is the length of σ

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[7] $e \cdot_E e'$ is a partial function that is defined only if $\beta(e) = \alpha(e')$. In this case one gets $e \cdot_E e' = e''$ iff $e \sqsubseteq_E e'' \wedge e' \sqsubseteq_E e'' \wedge \forall e^*[e \sqsubseteq_E e^* \wedge e' \sqsubseteq_E e^* \rightarrow e'' \sqsubseteq_E e^*]$. According to this definition, $\cdot_E$ is the join-operation on E restricted to events e and e' with $\beta(e) = \alpha(e')$.

$\phi_3\ [D_{DET}, E', \theta_{TR}, N_{CN}]$ expresses the quantificational condition QC, i.e., one has: $\tau(E'), k \models \phi_3\ [D_{DET}, E', \theta_{TR}, N_{CN}]$ iff $G'_{E',\theta_{TR}}(\langle s_0, ..., s_k\rangle) = Z$ and $D_{DET}(N_{CN})(Z)$. The property defined in (34) is satisfied only if $D_{DET} = D_{bare}$. According to (34), in the case of the quantificational condition QC the invariance is defined with respect to sub- and supersequences that are execution-sequences of events that belong to the same event-type $[E']_{\theta_{TR},N_{CN}}$. At the level of $[E']_{D_{DET},\theta_{TR},N_{CN}}$ (34) means that this type is closed under (non-empty) subsets and supersets belonging to $[E']_{\theta_{TR},N_{CN}}$. Local and global durativity w.r.t. QC at level n can now be defined as follows.

(a) a verbal expression is not locally durative w.r.t. QC at level $n = 0$

(b) a verbal expression is locally durative w.r.t. QC at level $n > 0$ iff (37a) holds for all events E' that are introduced at that level

(c) a verbal expression is globally durative w.r.t. QC at level $n > 0$ iff it is locally durative w.r.t. QC at some level m with $1 \leq m \leq n$.

There is the following difference between the RC and the QC. The RC applies to single sets of events E'. It does not matter whether it is an invariant for all elements of $[E']_{D_{DET},\theta_{TR},N_{CN}}$. Thus, (P2) does not express a property of the binary relation corresponding to the set $[E']_{D_{DET},\theta_{TR},N_{CN}}$ because it does not hold for all sequences belonging to this relation. Rather, there are sequences that satisfy (P2) and there are sequences for which (P2) does not hold. (P3), on the other hand, requires that the closure-conditions (i) and (ii) hold for all events $E' \in [E']_{D_{DET},\theta_{TR},N_{CN}}$. In this respect (P3) is similar to (P1) that applies to the elements of an event-type P_v. (P1) too requires that the result brought about by events of this type is an invariant for all events $e \in P_v$.

According to (32), the execution-sequences of events e that belong to an event-type P_v with $\gamma(P_v) = R_{\text{Con-BEC}}$ can be interpreted as the n-fold product of executions of events of this type with $e = e_1 \cdot_E\ ...\ \cdot_E e_n$, $1 \leq i \leq n$, each $e_i \in P_v$, $e_i \sqsubseteq_E e$ and $\beta(e_i) \in \delta(P_v)(\rho(P_v)(e))$. For the execution-sequences of sets of events that are denoted by expressions with bare plural NPs something similar holds.

Let $[e]_{D_{DET},\theta_{TR},N_{CN}}$ be the set of all events $e \in E$ that is defined for θ_{TR} and for which the value of θ_{TR} is a subset of N_{CN} satisfying $D_{DET}(N_{CN})(\theta_{TR}(e))$, (35a). The binary relation $R^*_{[e]_{D_{DET},\theta_{TR},N_{CN}}}$ that corresponds to (35a) is given in (35b).

(35) a. $[e]_{D_{DET},\theta_{TR},N_{CN}} =$
$$\{e \in E \mid \exists Y[\theta_{TR}(e) = Y \wedge Y \subseteq N_{CN} \wedge D_{DET}(N_{CN})(Y)]\}$$
b. $R^*_{[e]_{D_{DET},\theta_{TR},N_{CN}}} = \{\sigma \in S^* \mid \exists e \in [e]_{D_{DET},\theta_{TR},N_{CN}} : \tau(e) = \sigma\}$

The execution-sequence $\tau^*(I(e))$ of each $e \in [e]_{D_{DET},\theta_{TR},N_{CN}}$ satisfies $\phi_3\ [D_{DET}, I(e), \theta_{TR}, N_{CN}]$ at its output-state. This property is not lost if instead of elements from $[e]_{D_{DET},\theta_{TR},N_{CN}}$ (non-empty) subsets of this set are considered, that is elements from $[E']_{D_{DET},\theta_{TR},N_{CN}}$. $R_{[E']_{D_{DET},\theta_{TR},N_{CN}}}$ can therefore be interpreted as a kind of iteration with respect to $R^*_{[e]_{D_{DET},\theta_{TR},N_{CN}}}$. The elements of $R^*_{[e]_{D_{DET},\theta_{TR},N_{CN}}}$ are the execution-sequences of events e for which θ_{TR} is defined such that $\theta_{TR}(e) \subseteq N_{CN}$ and $D_{DET}(N_{CN})(\theta_{TR}(e))$. The elements of $R_{[E']_{D_{DET},\theta_{TR},N_{CN}}}$ are (non-empty) subsets of $R^*_{[e]_{D_{DET},\theta_{TR},N_{CN}}}$. They correspond therefore to the execution of a finite number $n > 0$ of events that belong to $[e]_{D_{DET},\theta_{TR},N_{CN}}$.

Finally, global durativity at level n is defined as follows.

(36) A verbal expression is globally durative at level n iff
(i) it is globally durative w.r.t. RC at level n and
(ii) it is globally durative w.r.t. QC at level n

From the definitions of global durativity w.r.t. RC and global durativity w.r.t. QC it follows that a verbal expression is globally durative at level n if it is locally duratitive w.r.t. QC at some level m such that $m \leq n$ or if it is locally durative w.r.t. RC for all levels m with $m \leq n$, i.e. for all levels lower n, including the level n.

The aspectual restriction imposed by a *for*-adverbial is explained as follows. A *for*-adverbial is admissible at level n only if the verbal expression is globally durative at that level. This restriction is not directly imposed by a *for*-adverbial. Rather this type of adverbial imposes a requirement on the execution-sequence of the set of events E' that is introduced (or presupposed) at level n. This requirement is satisfied only if the expression is globally durative at level n

Let E' be the set that is introduced (or presupposed) at level n and $W \subseteq N_{CN}$ be the set that is introduced (or presupposed) by the interpretation of the NP corresponding to level n; then either

(a) both the results Q that must be brought about by the elements of E' and the RC with respect to W are satisfied at each state of the execution sequence of E', except the source-state

or

(b) upon termination of each element of E' the QC is satisfied and the QC continues to be satisfied if more events of type P_v are executed

The first condition imposes a requirement on the actual execution-sequence of the set E', i.e., on the way the set E' occurs in time. Procedurally, it says that if the execution is stopped at an arbitrary point, then all requirements that are imposed both at the level of the elements of E' and at the level of E' are satisfied. This condition is satisfied only if $\gamma(P_v) = R_{\text{Con-BEC}}$ and the elements of W are processed simultaneously, i.e., if the expression is globally durative.

The second condition does not impose a requirement on the actual execution. Procedurally, it says that independently of how many events of type P_v are executed that θ_{TR}-process a subset of N_{CN}, the QC is satisfied. This condition is satisfied only if $DET = BARE$ and if this condition is satisfied, the expression is globally durative.

Singular, non-mass NPs and bare plurals are aspectually similar in the following sense. Neither can give rise to local non-durativity at a level $n > 0$. Singular, non-mass NPs are never locally durative w.r.t. QC at level $n > 0$. On the other hand, they are always locally durative w.r.t. RC at a level $n > 0$. This follows from the fact that they cannot spawn a set of processes because the set introduced (or presupposed) by this type of NP is always a singleton. In this case the RC is trivially an invariant of the execution-sequence of this singleton. Bare plural NPs, on the other hand, need not be locally durative w.r.t. RC. If a non-singleton set W is denoted, this depends on the way the events are executed, either simultaneously or non-simultaneously. Yet, a bare plural that occurs as argument at level n leads to global durativity at all levels $m \geq n$. This follows from the fact that the execution-sequences of sets of events introduced by a bare plural always satisfy (P3) which is sufficient for local durativity w.r.t. QC. The latter in its turn is sufficient for global durativity at all levels equal to or higher than n.

4.3 Bare Plurals and Modification with in-Adverbials

In section (1) several examples of expressions with bare plurals that admit of modification with both *in*- and *for*-adverbials were discussed.

(37) John filled a bottle with marbles in ten minutes/for ten minutes.

If modification with a *for*-adverbial is possible, the bottle need not be completely filled but only to a certain degree, say, halfway. On the other hand, modification with an *in*-adverbial requires the bottle to be filled completely. On the first reading (37) can be paraphrased by 'John put marbles into a bottle' whereas on the second reading the sentence is equivalent to 'John filled marbles into a bottle until it was full'. These two possibilities can be accounted for if (the interpretation of) 'fill' only requires that part of the object denoted by the internal argument is filled and not necessarily the whole object, leaving it open whether the maximal value (the object is full) is reached or only some value in between (the object is partly filled). According to this analysis, a verb like 'fill' is underspecified with respect to the result that is determined in the lexicon. The possibility of modification with both types of adverbial is an immediate consequence of this underspecification with respect to the result because there are two different types of execution-sequences. If the maximal result is reached, it only holds at the target-state, whereas in case a non-maximal result is reached, this result holds at all intermediate states of the execution.

What is common to both types of executions is that the putting of a marble into the bottle corresponds to a partial filling of it, i.e., the minimal result is satisfied. From this it follows that the set of events that is introduced by the interpretation of the oblique argument ('with marbles') contributes to the obtaining of the global result that is reached, i.e., either the complete filling of the bottle or the partial filling of it. This global result is brought about by the set of events that is introduced at the level of the VP 'fill a bottle' (or, more generally, 'fill NP_{int}'). This set is either a singleton, if the internal argument NP is singular, as in (37), or it is a non-singleton set ('fill five bottles'). The oblique argument does therefore not introduce a further set of events in the way that is done by an external argument NP which has scope over the internal argument NP (recall the examples from section (4.1)). Rather, the elements of the set E' that is introduced by the oblique argument of 'fill' are subevents of the elements of the set that is introduced by the VP 'fill NP_{int}', i.e., each element e' of E' is a subevent of an event e'' of the set E'' if the latter is the set introduced by the VP. Even something stronger is true: the set E' has the same join as the set E'' introduced by the interpretation of the VP. Thus, the set E' introduced by the oblique argument structures a set of events that has already been introduced by specifying the type of its subevents, in particular by specifying the sort of object (or stuff) with which the object denoted by the internal argument is filled.

5 A Comparison with other Approaches[8]

5.1 Manfred Krifka's Approach

Recall the data in (38).

(38) a. John ate an apple in ten minutes/*for ten minutes.
b. John pushed the cart *in ten minutes/for ten minutes.
c. John ate apples *in ten minutes/for ten minutes.

In Krifka (1989, 1992) (see also Egg (1994) and Eberle (1996)) verbal expressions that admit of modification with *for*- but not of that with *in*-adverbials are called homogeneous, whereas those expressions that admit of modification with *in*- but not of that with *for*-adverbials are called heterogeneous (quantized). These notions are defined in the following way.

(39) a. $\forall P[HOMOG(P) \longleftrightarrow CUM(P) \wedge DIV(P)]$
b. $\forall P[CUM(P) \longleftrightarrow \forall e, e'[P(e) \wedge P(e') \rightarrow P(e \sqcup_E e')]]$
c. $\forall P[DIV(P) \longleftrightarrow \forall e, e'[P(e) \wedge e' \sqsubset_E e \rightarrow P(e')]]$
d. $\forall P[HETEROG(P) \longleftrightarrow \forall e, e'[P(e) \wedge e' \sqsubset_E e \rightarrow \neg P(e')]]$

Homogeneity is defined as the conjunction of cumulativity and divisivity. Heterogeneity is (strong) non-divisivity. The task is to show how this properties of verbal expressions can be proved from semantic properties of their parts. The basic assumption that is made by Krifka in order to explain the data in (38) is that there is a structural relationship or similarity between the event-domain E and the object-domain O. This relationship is expressed by means of mappings between the two domains E and O. These mappings correspond to properties of certain thematic relations R like *Patient* or *Agent* that are assigned by a verb to one of its argument places.

(40) a. $\forall R[GRAD(R) \longleftrightarrow \forall e, e', x[R(e, x) \wedge e' \sqsubset_E e \rightarrow \exists x'[x' \sqsubset_O x \wedge R(e', x')]]]$
b. $\forall R[CONSTANT(R) \longleftrightarrow \forall e, e', x[R(e, x) \wedge e' \sqsubset_E e \rightarrow R(e', x)]]$

Assuming that the VP 'eat an apple' is translated as (41), as this is done in Krifka (1992), one can prove that it is heterogeneous.

(41) eat an apple $\rightsquigarrow \lambda e \exists x[Eating(e) \wedge apple(x) \wedge Patient(e, x) \wedge num(x) = 1]$

The thematic relation *Patient* assigned by 'eat' to its internal argument is gradual: $GRAD(Patient_{eat})$. From $GRAD(Patient_{eat})$ it follows that any proper subevent e' of an event e which satisfies the predicate is related to only a proper part x' of x. But no proper part x' of an apple $(= x)$ will satisfy the predicate $num(x') = 1$ because x' is not a complete apple. Therefore x' does not satisfy the translation of the internal argument 'an apple'. Suppose now that $[\![\lambda e \exists x[Eating(e) \wedge apple(x) \wedge Patient(e, x) \wedge num(x) = 1]]\!](e) = 1$. Then for all $e' \sqsubset_E e$ it holds that $[\![\lambda e \exists x[Eating(e) \wedge apple(x) \wedge Patient(e, x) \wedge num(x) = 1]]\!](e') = 0$. But this means that, according to definition (40a), the event predicate in (41) is heterogeneous. In the case of 'eat apples' the situation is different. Here the condition on the cardinality is '$\exists n[num(x) = n]$'

[8] For an extensive discussion of how the approach developped in this paper relates to those of Dotwy (1979) and Verkuyl (1993) see Naumann (1995), chapter 2 (Dowty) and chapters 4 and 5 (Verkuyl).

which is satisfied for all proper parts x' of x. Therefore, the VP is not quantized (heterogeneous). Note that the proofs do *not* refer to the cardinality of the set denoted by the argument NP but only to the way it refers to its denotation (either homogeneously or heterogeneously).

In the case of 'push a cart' the argument runs as follows. The Patient-role that is assigned by the verb 'push' to its internal argument is constant: $CONSTANT(Patient_{push})$. From this it follows, (40b), that each subevent e' of an event e that satisfies the event predicate $\lambda e \exists x[Pushing(e) \wedge cart(x) \wedge Patient(e,x) \wedge num(x) = 1]$ is related to the whole cart x. Therefore, $cart(x) \wedge num(x) = 1$ is satisfied such that $\lambda e \exists x[Pushing(e) \wedge cart(x) \wedge Patient(e,x) \wedge num(x) = 1]$ is divisive.[9] Now suppose that $\lambda e \exists x[Pushing(e) \wedge cart(x) \wedge Patient(e,x) \wedge num(x) = 1]$ is satisfied by an event e and by an event e' for some cart x. Then the sum-event $e \sqcup_E e'$ still satisfies the predicate because $Pushing(e \sqcup_E e')$ (this follows from the cumulativity of $Pushing$ and the fact that for each two events e and e' the sum- event $e \sqcup_E e'$ exists), $cart(x \sqcup_O x) \wedge num(x \sqcup_O x) = 1$ and $Patient(e \sqcup_E e', x \sqcup_O x)$ ($Patient$ is summative) hold. Note that this argument is valid only if it is assumed that the same cart x is pushed. Therefore, the predicate is cumulative. When taken together, one gets the desired result that $\lambda e \exists x[Pushing(e) \wedge cart(x) \wedge Patient(e,x) \wedge num(x) = 1]$ is homogeneous.

The proofs have shown that the thematic relations together with the referential properties of the argument NP determine the aspectual properties of the (complex) event-predicate. The basic assumption made by Krifka can now be formulated in the following way. The aspectual properties of a verbal projection depend (i) on the properties of the thematic relation that is assigned to the NP with which the projection was combined at that level and (ii) on the referential properties of that NP. In particular, one gets the two claims in (42).

(42) a. An argument NP can influence the aspectual properties of the verbal expression it combines with only if the thematic relation has the property of graduality. If the role has the property of being constant, no transfer of referential properties is possible. Another way of expressing this distinction is to say that the thematic relations determine whether there is a transfer of referential properties from the object domain to the event domain. Gradual roles license a transfer of referential properties from O to E whereas constant roles do not licence such a transfer.

b. The aspectual properties of a verbal projection depend only on the properties of the thematic relation(s) and the referential type of the argument-NP(s), i.e., that of being quantized or that of being homogeneous. In particular, the properties do not depend on the cardinality of the objects denoted by the NPs. For instance, whether a VP of the form 'V DET N' is quantized or not can be calculated solely on the basis of the properties of the thematic relation assigned to the NP 'DET N' and the referential properties of that NP.

The discussion of the data in section (1) has shown that both assumptions are wrong. According to the first assumption, only NPs with gradual roles should be able

[9] Note that the property of divisivity is not used by Krifka to distinguish 'push a cart' from 'eat an apple'. Rather he uses only the property of cumulativity. But, as noted in Eberle (1996), Egg (1994) and Naumann (1995), this leads to problems. A VP like 'eat more than five apples' is cumulative and not heterogeneous such that according to Krifka it should aspectually behave like 'push a cart', contrary to the data: 'eat more than five apples in ten minutes/*for ten minutes'.

to influence the verbal expression they combine with. But examples like (8a) and (8d) show that also external arguments that are assigned constant roles can have an influence on the aspectual properties.

(8) a. Students crossed the street *in an hour/for an hour.
d. Tourists discovered this quaint little village *in one year/for years.

Although the VPs are terminative (heterogeneous), the sentences are durative (homogeneous). The question is how this influence can be explained. According to Krifka (1989, 1992) the thematic relation corresponding to the external argument of a transitive verb is constant because there is no gradual mapping between its denotation and the event denoted by the verb. From (42a) it should then follow that there is no transfer of referential properties from O to E, i.e., a bare plural in subject position should leave the aspectual properties of the VP unchanged. But the examples (8a) and (8d) show that this is not the case. It follows that this influence must be explained in a way that is different from the influence an internal argument has. This has two consequences. First, the influence of a bare plural is explained differently, depending on the argument position it occurs in. But this is counterintuitive. The semantic (referential) properties of such an NP are independent of the argument position it occurs in and should therefore always influence the aspectual properties in the same way.[10] Second, and more importantly, if Krifka is obliged to assume at least one other mechanism besides that which is defined by the mapping between O and E, this means that aspectual influences are not always based on such a mapping. One may argue that if the argument is plural as in the examples (8a) and (8d) then there is in effect a mapping from O to E. For instance, in the case of (8a) one can argue that each student corresponds to a part of the event, namely that part where it has been involved. A similar argument holds for (8d). In order to explain the shift in aspectual behaviour from the level of the VP to the level of the untensed sentence one can then apply the same reasoning that was used for 'eat apples'. The problem that Krifka faces is how this idea can be integrated into the framework. So far, a thematic relation is either constant or not, irrespective of the cardinality of the object denoted by the argument. But the reasoning above necessitates a change: whether a role is constant or not (i.e. gradual) depends in general on the object that is denoted by the argument. Plural NPs can give rise to a gradual role, irrespective of whether they are bare or non-bare, whereas this is not possible if the object is singular (atomic). Even if this problem is solved, one is forced to assume that it is not necessarily the way how the NP refers to its denotation (quantized vs. homogeneous) but rather the cardinality of the denotation which is relevant. Thus if he succeeds in saving assumption (42a), he has to give up assumption (42b). In the theory developed in this paper this problem is solved by the functions $G^i_{E',\theta_{TR}}$ defined in (21). What is important is the way a set of objects W that is θ_{TR} related to a set of events E' is linked to the execution sequence of E'. If all elements of W are processed by the elements of E' at the same time, one gets constancy, i.e., the whole set W is involved at all intermediate states of the execution sequence. This corresponds exactly to the way a constant role

[10] Furthermore, if one assumes that the influence of a bare plural depends on the argument position it occurs in, it is, in effect, a property of the argument position that is used to explain the aspectual influence. As this property must be distinct from the properties of the thematic relation assigned by the verb to the argument, one faces the problem of having to determine a further property that can be used in explaining the influence of NPs on the aspectual behaviour of verbal expressions.

is defined, (40b). If the elements of W are not processed simultaneously, one gets a form of graduality, i.e., thar are intermediate states of the execution at which only a proper subset of W has been processed. Note that on this analysis a verbal expression is underspecified with respect to its aspectual properties. Depending on a particular context in which a set of events E' is executed in a particular way, the expression is either durative or non-durative (at some level n).

A problem similar to that posed by the examples in (8) is posed by the examples in (2).

(2) a. push five carts in ten minutes/for ten minutes
b. push five carts successively in ten minutes

Although the verb assigns a constant role to its internal argument, a heterogeneous (quantized) interpretation is possible, (2b). The difference to the previous case is that here a homogeneous expression becomes quantized. On the present account the constancy applies to the way the result determined in the lexicon is evaluated on the execution sequences of the single events: it is satisfied at all intermediate states because the dynamic mode assigned to P_{push} is $R_{\text{Con-BEC}}$. This is similar to the way Krifka argues. But in addition there is the level of the referential condition and the way it is satisfied on the execution sequence of the set of events E' corresponding to the three pushings. The latter is determined by the functions $G^{i}_{E',\theta_{TR}}$ for $TR = PATIENT$. For a non-simultaneous execution $G''_{E',\theta_{TR}}$ is not constant such that one gets a form of graduality with respect to the referential condition. Non-constancy of $G''_{E',\theta_{TR}}$ is possible only if the set W denoted by the argument NP to which TR is assigned has cardinality greater 1. The discussion can be summarized as follows.

(i) Graduality (or, more generally, non-constancy) of a thematic relation is not a necessary condition for a terminative (heterogeneous) interpretation of a verbal expression.

(ii) The influence of NPs depends on the cardinality of the set introduced or presupposed by it

(iii) The influence of NPs does not depend on the argument-position they occur in.

(i) can be regarded as a consequence of (iii). If an NP can influence the aspectual properties of verbal expressions it combines with independently of the argument-position it occurs in, this influence is independent of the thematic relations assigned by the verb to its arguments. The conclusion to be drawn from this independence is that if there is any transfer of referential properties from the object-domain O to the event-domain E, it is not the only mechanism that can lead to terminativity (heterogeneity).

On the analysis developed in this paper, the independence of the influence of NPs of the argument-position is due to the fact that similarly to VPs NPs do impose conditions that (sets of) events must satisfy. Two such conditions are distinguished: the referential condition (RC) and the quantificational condition (QC). The RC depends on the cardinality of the set corresponding to the NP. Only sets W with $|W| > 1$ can give rise to local non-durativity w.r.t. RC because only then is it possible that the RC is not an invariant of the execution-sequence of the set of events E' that processes the elements of W. Thus, the principle distinction on which RC is based is that between NPs introducing or presupposing a set W of cardinality 1 and those NPs for which the cardinality of W is greater than 1. In contrast to the referential condition RC the quantification condition QC is based on a distinction similar to that between homogeneity and heterogeneity used by Krifka. The principle distinction in this case is that between NPs that impose a QC such that for a given set W that satisfies this QC also each (non- empty) subset of W and each superset of W satisfies the QC. In contrast to Krifka (1989, 1992), the influence that this distinction has on the aspectual properties of verbal expressions is independent of any thematic roles. According to Krifka (1989, 1992), the principle distinction between NPs is that between those that refer homogeneously and those that refer heterogeneously[11]. This distinction sets bare plural (and mass) NPs apart from all other NPs (singular, non-mass and non-bare plural) because the former have homogeneous reference whereas the latter refer heterogeneously. On the present analysis the distinction must rather be made between singular, non-mass NPs and bare plurals on the one hand and non-bare plural NPs on the other. Whereas singular, non-mass NPs cannot give rise to non-durativity w.r.t. RC, bare plural NPs cannot give rise to non-durativity with respect to QC.

At each level, result, RC and QC, it is possible to get a form of graduality. At the level of single events this is the case if the result is brought about in the way determined by $R_{Min-BEC}$. If the execution sequence of e is an element of $R_{Min-BEC}(Q)$, then the result Q does not hold for each proper subevent e' of e (for more details, see Naumann 1999). At the level of RC one gets graduality if $G''_{E',\theta_{TR}}$ is not constant and, finally, at the level of QC one has graduality if (34a) does not hold. At each level a structural relationship is defined. The dynamic modes establish a structural relationship between E and $\wp(S)$; the functions $G^i_{E',\theta_{TR}}$ define a mapping between $\wp(E)$ and $\wp(O)$ and (34a) establishes a mapping between $\wp(E)$ and $\wp(E)$. For that reason, Krifka's idea that aspectual phenomena must be explained on the basis of structural relationships between different domains, including a domain of events, is accounted for in the present approach.

Furthermore, the approach developed in this paper does not face the following problem. Recall that the event predicate in (41) is heterogeneous (quantized). This means that no proper subevent e' of an event e satisfying this predicate satisfies it. Yet, there are counterexamples to this claim.

(43) a. John pushed the cart to the station.
b. Mary closed the door.

If Mary closed the door, then each (non-minimal) final stage of this event is also of type '(Mary) close the door'. This means that if an event e belongs to the denotation of '(Mary) close the door', then also each (non-minimal) final stage e' of e belongs to this denotation. An analogous argument applies to (43b). This immediately implies that the expression is not quantized, contrary to what is expected according to its aspectual behaviour (modification with *in*-, but not with *for*-adverbials). The problem is due to the fact that the property of being quantized is too strong. It quantifies over all proper subevents, in particular over all (proper) final stages of an event. The examples in (43) show that this class of subevents must be excluded because they can be of the same type as the original event e. Furthermore, as shown in Naumann

[11] This follows directly from the way aspectual properties of complex event predicates are proved. For instance, the proof that the event predicate in (41) is quantized recurs to the fact that the internal argument NP has quantized reference but does not make use of any cardinality information.

(1999), intermediate stages of e do not play a role for aspectual classification. Rather, what must be excluded are initial stages (prefixes) of e. This is exactly what is done by $R_{Min-BEC}$ defined in (10a). If the execution-sequence $\tau(e)$ of an event e belongs to $R_{Min-BEC}(Q)$, no proper prefix of $\tau(e)$ is an element of $R_{Min-BEC}(Q)$.

(44) $\forall\sigma[\sigma \in R_{Min-BEC}(Q) \rightarrow \forall\sigma'[prefix(\sigma', \sigma) \rightarrow \sigma' \notin R_{Min-BEC}(Q)]]$

The basic intuition behind the notion of graduality is that the object which is gradually involved in an event is completely processed only upon termination of the event, i.e. at its end-point. For a constant role, on the other hand, the corresponding object is already completely involved during the event, i.e. before it terminates. For instance, in the case of an event of type 'close the door' the door is completely closed only when the event terminates. From this intuition it does not follow that *each* subevent of this event must not be of the same type. What is important, rather, is that the condition that the door being closed is not satisfied for any proper initial stage of a given event of closing the door. But this means that what is important is exactly the relation of being a (proper) initial stage of. This example also shows that the basic intuition of Krifka's approach that there is a mapping between the event e and some quantity is preserved in the present approach. From (44) it immediately follows that no proper initial stage e' of e brings about Q. In contrast to what is assumed by Krifka, this mapping is defined not in terms of e and some object x and its material parts but rather in terms of e and one of the properties of x. This relationship is directly expressed in the dynamic mode characterizing an aspectual class. The shift from x and its material parts to a property of x is necessary because of examples like those in (45).

(45) a. John peeled the apple.
b. John built a house.

Example (45a) shows that even if some object is incremental with respect to material parts, it need not be incremental with respect to all material parts. If an apple is peeled, only its surface is involved and no other parts such that not each part corresponds to a part of the event of peeling. Example (45b) shows that not each part of an event need correspond to a (material) part of the incremental object. If a house is built, one first erects a scaffold. But this scaffold is not part of the (finished) house.[12]

5.2 James Pustejovsky's Approach

Pustejovsky (1991) (see also Pustejovsky/Bouillon 1996)distinguishes three different sorts of event-types: states, processes and transitions. Processes are defined as sequences of events identifying the same semantic expression: $P = \langle e_1, ..., e_n \rangle$. A transition, on the other hand, is an event that identifies a semantic expression that is evaluated relative to its opposition. For instance, for the sentence 'The door closed' the opposition is that between the door not being closed and the door being closed. This opposition is brought about by a process such that a transition can also be conceived of as a pair $[P, S]$ consisting of a process and a state where S is the state of the door being closed and P can be described by the formula 'become(closed(the door))'.

[12] These problems are acknowledged by Krifka (1992).

On Pustejovsky's approach the distinction between process, which are denoted by activity-expressions, and transitions, which are denoted either by accomplishment- or achievement-expressions, therefore is that the latter but not the former involve an opposition. At first sight the characterization of processes as not involving an opposition seems to be incompatible with that given in the approach developed here where events that are denoted by non-stative verbs always bring about a change (transformation) of state that involves an opposition between what holds at the source-state of the event and at its target-state. Yet there is the following alternative interpretation. The definition of processes as sequences of events that are denoted by the same semantic expressions can be understood in the sense that a process is the repeated execution of events that belong to the same event type P_v. In terms of a progam from DL a process therefore corresponds to an iteration. But this is exactly one way of how activity-expressions can be interpreted in the present approach. Recall that events denoted by activity-expressions with verb v are only required to bring about the minimal result that is assigned to events of type P_v. This condition is satisfied for each event $e \in P_v$. As a consequence, it is not necessary to explicity specify that an event denoted by an activity-expression is required to bring about the minimal result. It is sufficient to require that at least one event $e \in P_v$ is executed that satisfies the conditions that are imposed by the thematic relations. But this means that the requirement that an activity-expression imposes can be formulated in terms of an iteration: execute at least one event of type P_v (that is related to the required objects). If this requirement is satisfied, it already follows that a minimal change is brought about. The execution sequence of the event e that is the sequential composition of the sequence of events $\langle e_1, ..., e_n \rangle$, $e_i \in P_v$ for $1 \leq i \leq n$, is an element of $R_{\text{Con-BEC}}(Q)$ for Q the minimal result assigned to e.[13]

An opposition in the sense of Pustejovsky can therefore not be identified with any transformation of state, in particular not with a minimal transformation of state. Rather such an opposition corresponds to a transformation of state in which the result that is brought about only holds at the target-state of the corresponding event and that is not guaranteed to hold after the execution of an arbitrary number of events of type P_v. Transitions therefore correspond to sequences of events of the same type that are required to bring about a non-minimal result. This does *not* exclude that activity- and accomplishment-expressions denote the same sequence of events. For instance, 'John pushed the cart' and 'John pushed the cart to the station' can both be used to describe the same event. The difference between the two expressions, rather, lies in the condition that is imposed on the result that has to be brought about. For 'John push the cart' it is only required that the cart traverses a non-empty path relative to the source-state of the event whereas for 'John pushed the cart to the station' it is required that the cart is at (or in) the station upon termination of the event.

6 Conclusion

In this paper the notion of durativity has been defined in terms of invariance-properties of execution-sequences of events or sets of events. Three types of durativity were dis-

[13] This interpretation of processes is supported by the way Pustejovsky analyzes activtity-expressions like 'Mary pushed the cart'. Their translation involves a predicate 'move' that denotes a change of location: Mary pushed the cart $\rightsquigarrow$ cause(act(mary,the-cart), move(the-cart)).

tinguished. First, durativity with respect to the result brought about by single events e. This type of durativity is used to (partially) make aspectual distinctions between verbs in the lexicon. At that level the accessibility relation is $< \sigma$ for $\sigma = \tau(e)$. The invariance is expressed by the box-modality $\Box$ (i.e. $[< \sigma] = \mathbf{G}$,). Second, there is durativity with respect to the referential condition RC. This type of durativity is used to aspectually distinguish non-bare plural NPs from other types of NPs. The accessibility relation is $< \sigma$ for $\sigma = \tau(E')$. Similar to the first type of durativity the invariance is expressed by the box-modality $\Box$ ($[< \sigma] = \mathbf{G}$). The third type of durativity is durativity with respect to the quantificational condition QC. In this case there are two accessibility relations: $\subseteq^*$and $\supseteq$ (' $\subseteq^*$' is the subset relation that excludes the empty set). Given the set of sequences $\Sigma = \tau^*(E')$ of a set of events E' that satisfies the QC, durativity is defined with respect to (non-empty) subsets Σ' and supersets Σ'' of $\tau^*(E')$ that are the set of sequences corresponding to (non-empty) subsets and supersets of E' that belong to the event-type $[E']_{\theta_{TR},N_{CN}}$. As in the other cases the invariance is expressed in terms of the box-modality $\Box$ ($[\subseteq^*] = \downarrow$and $[\supseteq] =\uparrow$).

7 Appendix

A dynamic event-structure **ES** is a tuple
$\langle \mathbf{E}, \mathbf{S}, \mathbf{O}, \alpha, \beta, \gamma, \delta, \rho, \{D_{DET}\}_{DET \in DT}, \{PR_{pr}\}_{pr \in PROP}, \{\theta_{TR}\}_{TR \in THR} \rangle$ such that

- $\mathbf{E} = \langle E, \sqsubseteq_E, \cdot_E, \{P_v\}_{v \in VERB} \rangle$ is an eventuality-structure with
  - E is a (non-empty) set of events
  - $\sqsubseteq_E \subseteq E \times E$ is a reflexive, antisymmetric and transitive relation (the part-of relation on E)
  - the P_v are unary relations on E (called event-types);
  - $VERB = \{eat, drink, run, push, hit, ...\}$ corresponds to (a subset of) the (non-stative) verbs in English
  - $\cdot_E : E \times E \to E$ is a partial function that is defined for a pair (e, e') only if $\alpha(e') = \beta(e)$; in this case $e \cdot_E e' = e$" iff $e \sqsubseteq_E e'' \wedge e' \sqsubseteq_E e'' \wedge \forall e^*[e \sqsubseteq_E e^* \wedge e' \sqsubseteq_E e^* \to e'' \sqsubseteq_E e^*]$
- $\mathbf{S} = \langle S, <, S^*, \{R_{OP}\}_{OP \in DM} \rangle$ is a transition-structure with
  - S is a (non-empty) set of states
  - $<$ is a linear and discrete ordering on S
  - S^* is the set of finite sequences based on S that respect the ordering $<$ on S (i.e., S^* is the set of finite convex subsets of S). Elements from S^* will be written σ (possibly primed) or as (s, s') where s and s' are the beginning- and end-point of the sequence, respectively
  - each R_{OP} is a dynamic mode, i.e. a function that maps properties of states (unary relations on S) to binary relations on S (or, equivalently, to sets of (finite) sequences). **S** is standard if the R_{OP} are interpreted as follows. $DM = \{Min-BEC, Con-BEC, HOLD\}$

  $R_{Min-BEC} =$
  $$\lambda Q \lambda s s'[s < s' \wedge \neg Q(s) \wedge Q(s') \wedge \forall s''[s < s'' < s' \to \neg Q(s'')]]$$
  $R_{\text{Con-BEC}} =$
  $$\lambda Q \lambda s s'[s < s' \wedge \neg Q(s) \wedge Q(s') \wedge \forall s''[s < s'' < s' \to Q(s'')]]$$
  $R_{HOLD} =$

$\lambda Q\lambda ss'[s \le s' \wedge \forall s''[s \le s'' \le s' \rightarrow Q(s'')]]$

The R_{OP} are used to characterize aspectual classes

- $\mathbf{O} = \langle O, \sqsubseteq_O, \{N_{CN}\}_{CN \in NOUN}\rangle$ is an object-structure with
  – O is a (non-empty) set of objects
  – $\sqsubseteq_O \subseteq O \times O$ is a reflexive, antisymmetric and transitive relation (the part-of relation on O)

  each N_{CN} is a unary relation on O; $NOUN = \{MAN, CAR, ...\}$ is a subset of the count nouns in English

- α and β are functions $E \rightarrow S$ which assign to each event its source-state $\alpha(e)$ and target-state $\beta(e)$, respectively. It is required that $\forall e[\alpha(e) \le \beta(e)]$. The product-mapping $\langle \alpha, \beta \rangle\ (=\tau) : E \rightarrow S \times S$ assigns to each event e its execution-sequence $\tau(e)$. As each event e has a source- and a target-state, it follows that the execution-sequences of events are finite. Note that $\tau(e)$ is used ambiguously. It is either the pair $(\alpha(e), \beta(e))$ or the set $\{s \in S \mid \alpha(e) \le s \le \beta(e)\}$. This is justified because each pair (s, s') of states uniquely determines the set $\{s'' \in S \mid s \le s'' \le s'\}$ and each uniquely determines a pair (s, s') such that $s = first(\sigma)$ and $s' = last(\sigma)$ where $first(\sigma) = s$ iff $s \in \sigma \wedge \forall s'[s' \in \sigma \rightarrow s \le s']$ and $last(\sigma) = s$ iff $s \in \sigma \wedge \forall s'[s' \in \sigma \rightarrow s' \le s]$. The function τ is extended to (finite) sets of events E': $\tau(E') = join(\Sigma)$, where $\Sigma = \{\sigma \in S^* \mid \exists e \in E' \colon \tau(e) = \sigma\}$; $join := \lambda\Sigma\imath\sigma[\forall\sigma'[\sigma \circ \sigma' \longleftrightarrow \exists\sigma''[\Sigma(\sigma'') \wedge \sigma'' \circ \sigma]]]$; $\sigma \circ \sigma'$ iff $\exists s : s \in \sigma \wedge s \in \sigma'$. The restriction to finite sets E' means that $\tau(E')$ is finite too. α and β respect $\cdot_E$ as follows. If $e'' = e \cdot_E e'$, then $\alpha(e'') = \alpha(e)$ and $\beta(e'') = \beta(e')$. From this one gets $\tau(e \cdot_E e') = \tau(e) \cdot_{S^*} \tau(e')$, where $\cdot_{S^*}$ is the fusion-operation on S^*.

- γ is a function that assigns to each P_v a dynamic mode, i.e. a function that maps properties of states to binary relations on S (or, equivalently, to a subset of S^*); the assignment is done in accordance with the aspectual class to which P_v belongs; for instance, $\gamma(P_{eat}) = R_{Min-BEC}$ and $\gamma(P_{push}) = R_{\text{Con-BEC}}$.

- δ is a function that assigns to each P_v some PR_{pr}. If $X = [\rho(P_v)](e)$ for some completed event $e \in P_v$, $\delta(P_v)(X)$ is the postcondition brought about by e

- ρ is a partial function that assigns to a P_v and an event $e \in E$ the set of objects with respect to which e effects a change. ρ is defined only if $e \in P_v$.

- each PR_{pr} is a relation on $\wp(O) \times S$.

- each θ_{TR} is a partial function from E to $\wp(O)$ that corresponds to a thematic relation that is used to link the 'ordinary' arguments to the event argument of a verb in event-semantics. $THR = \{AG(ent), PAT(ient), ...\}$ is a set of thematic relation signs. The functions θ_{TR} are extended to sets of events E' as follows: $\theta_{TR}(E') = \cup\{Y' \mid \exists e \in E' \colon \theta_{TR}(e) = Y'\}$.

- each D_{DET} is a binary relation on $\wp(O)$.

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