From Verkuyl to Krifka in One Article

Towards a Unified Theory of Aspectual Composition

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1. Introduction

In the past decades the work on aspectual composition has been mainly concerned with how quantificational information and event structure interrelate and what the consequences of this are for the view on the nature of events. Verkuyl (1972,1987, 1993) and Krifka (1986,1989a,1989b) are univocal in this respect; to understand the role of quantificational information in the determination of the aspects, it is assumed that accomplishments and activitities, taken to be primitive categories in Vendler's (1957,1967) quadripartition, should be decomposed. While activities and accomplishments share a component of gradual change, accomplishments differ from activitities in the presence of a natural culmination point. Imposing a mapping between the nominal structure and the event structure can account both for the idea of gradual change and the fact that quantificational information induces a culmination point.

This consensus of how to deal with aspectual (de)composition at a conceptual level contrasts sharply with the different points of view taken by Verkuyl and Krifka at the formal level. Leaving aside the differences between Verkuyl's set-theoretical versus Krifka's lattice-theoretical approach, it turns out that there are two obstacles standing in the way of a unified theory of aspectual composition. First, the formal constructs underlying the general notions of '(un)specified cardinality' (in the nominal domain) and 'presence/absence of a natural culmination point' (in the event domain) apply at different levels; while Verkuyl applies these constructs to specific collections and specific events, Krifka uses them to express properties of descriptions (reference properties), that is properties of sets of collections and sets of events as a whole. Second, even if the level of application were the same, the formal constructs would still be different. Verkuyl's bounded-unbounded opposition still differs sharply from Krifka's quantized-cumulative opposition.

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The aim of this paper is to bridge the formal gap between Verkuyl and Krifka. It is shown that Verkuyl's account can be 'lifted' to a higher-order setting whereby boundedness expresses a property of descriptions, while the predictions of the original theory are preserved. A priori such a prediction-preserving shift need not be feasible. Moreover, making boundedness into a reference property allows one to compare the notions unbounded versus cumulative and bounded versus quantized. It then remains to be seen which constructs yield the right results empirically, if they do at all.

Section 2 briefly outlines Verkuyl's theory. Section 3 goes into Krifka's notion of reference property. Section 4 modifies Verkuyl's account, lifting it to the level of reference properties. Section 5 compares the notions of (un)boundedness and cumulative/quantized.

2. Verkuyl: Aspectual composition

Verkuyl's theory of aspectual composition is best explained starting from an informal feature algebra. Noun phrases are assigned the feature [+SQA] or [–SQA] expressing a specified or unspecified quantity of A, where A refers to the noun set associated with the NP. Restricting our attention to accomplishments and activitities, verbs are specified for [+ADD_TO], thereby expressing intuitively 'ongoing activity'. VP-terminativity ([+T]), i.e. the presence of a natural culmination point at the level of VP, results when a [+ADD_TO] verb and a [+SQA] NP combine, otherwise VP-durativity ([–T]: absence of a natural culmination point) obtains.

The feature [±SQA] spells out as follows. The semantics of noun phrases results from lifting ($\uparrow$) the determiner D to a plural setting.[1,2]

(1) a. $\uparrow(D) = \lambda A \lambda P\, \exists X\, [D(A)(X) \wedge X \subseteq A \wedge [P \cap \wp(A)]\ \text{ps}\ X]$

Where [X ps Y] (X is a partition of Y) is defined as:

$\cup X = Y \wedge \varnothing \notin X \wedge \forall X', X'' \in X\, [X' \neq X'' \rightarrow X' \cap X'' = \varnothing]$

b. $\uparrow(\text{three'})(\text{table'}) = \lambda P\, \exists X\, [X \subseteq \text{table'} \wedge |X|=3 \wedge [P \cap \wp(\text{table'})]\ \text{ps}\ X]$

Under the lifting in (1a) A corresponds to the noun set and P to a plural, atemporal verbal predicate consisting of (possibly singular) collections (which are just sets). As is obvious from (1a), NPs are basically predicative under this view; for the NP *three tables* in (1b) the existential quantifier picks out a certain collection X consisting of three tables. It is at this point that the notion of [+SQA] applies: NPs that have an inherent cardinality specification like $|X|=3$ are [+SQA], while NPs that lack such a cardinality specification are [–SQA].[3]

To understand how this view on NPs connects with the event structure, first

Verkuyl's view on events is discussed. Verkuyl views events metaphorically as localistic paths where the intermediate locations are seen as counting points that keep track of the amount of temporal change up to and including that point. More formally, given that *d* is the type of individuals,[4] paths are functions p from the set of natural numbers (locations) into type ((d,t),t), the function space of sets of collections such that: a) paths start from scratch: $p(0) = \varnothing$, b) collections of predecessors are inherited: $p(n) \subseteq p(n+1)$, c) change is gradual in that at each next location we may add at most one collection $|p(n+1)-p(n)| \leq 1$ and d) if there is no change between two locations, then there is no change at any later stage: if $p(n)=p(n+1)$ then $p(n+2)=p(n)$. As an example figure 1 shows a possible path.

Under this definition paths are monotonically increasing: $n \leq m \rightarrow p(n) \subseteq p(m)$. Thus the set of collections assigned to the path is characterized by the set of collections assigned to the 'last' location: $[\cup_{n=1\ldots\infty} p(n)]$. At this point it can be seen easily how the event structure relates to the nominal domain. The atemporal predicate P in (1a) is equated with $[\cup_{n=1\ldots\infty} p(n)]$. Consequently the collection X picked out by the existential quantifier is spread in a cumulative way over the locations of the path. For instance, the collection associated with the path in figure 1 is {a,b,c,d,e}.

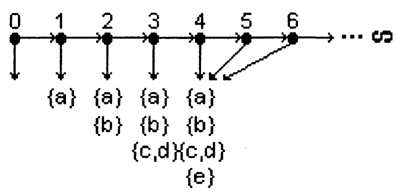

Figure 1.

Having established a mapping between the nominal structure and the event structure, the question how quantificational information determines the aspectual category is answered; a path p is taken to be terminative iff it contains a least fixed point n with $p(n)=p(n+1)$. In figure 1 the path has 4 as a least fixed point as 4 is the first location from where the set of collections remains constant. Terminativity occurs when there is no change anymore and is thus a property of a specific path. As a consequence finite collections must induce terminativity. For example non-increasing NPs like *less than 3 N*, *at most 100 N*, and *(exactly) 5 N* induce terminativity. Matters are different however for monotonically increasing NPs, including bare plurals. These NPs escape terminativity when they introduce a countably infinite collection.[5] To understand why bare plurals ([–SQA]) give rise to durativity whereas increasing NPs like *at least 3 N* ([+SQA]) induce terminativity, it seems that a stipulation is necessary: bare plurals necessarily introduce infinite collections, whereas increasing NPs containing a numeral must introduce finite collections. It remains to be seen whether this stipulation can be derived from some other source of information and whether there is some content to the claim that bare plurals introduce infinite collections.

Apart from this problem with using infinite path structures, there is the question of how paths relate to the temporal structure. Obviously paths should not be mapped on infinitely long intervals (at least not necessarily). Verkuyl proposes that actualization (i.e. the mapping from locations to time intervals) is conditional on the presence of the culmination point. Terminative paths are actualized until the least fixed point, whereas nonterminative paths are actualized until an arbitrary chosen cut-off point. Actualization furthermore ensures that the interval assigned to some location properly extends the interval assigned to its predecessor.

3. Krifka: Reference properties

Krifka observes a drawback of the approach put forward by Verkuyl. If the property of having a natural culmination point is a property of specific events/paths, then it cannot be explained why the durative (2) can be used to describe a situation in which John ate actually (say) 10 sandwiches.

(2) John ate sandwiches (for hours/* in an hour)

Krifka accounts for his observation in terms of the opposition between quantized and cumulative. The property of having a natural culmination point is a property of descriptions, a property of the way we refer. It is therefore best described as a property of a VP denotation, a set of events. The construct (i.e. formalized representation) underlying the presence of a natural culmination point is *quantized* (QUA). A description is quantized iff it does not refer to an event and a subevent thereof simultaneously (3a). The absence of a culmination point, in turn, is accounted for by *cumulative* (CUM), which says that a description is closed under the summation of events (3b).

(3) a. $\text{QUA(P) iff } P(e) \wedge e' \leq e \rightarrow \neg P(e')$ ($\leq$: part-of)
b. $\text{CUM(P) iff } P(e) \wedge P(e') \rightarrow P(e \oplus e')$ ($\oplus$: join)

These reference properties apply equally well in the nominal domain. A predicative noun phrase (denoting a set of collections) is quantized iff it does not apply at the same time to some collection and a subcollection thereof, while it is cumulative iff it is closed under grouping of collections. Under this definition non-monotonous predicative NPs[6] like *(exactly) three books* come out quantized and the increasing ones come out cumulative. Since in Krifka's system bare plurals are among the increasing, predicative NPs, again it turns out to be difficult to differentiate cardinal expressions and bare plurals.

To account for the fact that quantificational information induces terminativity (or *telicity* in Krifka's terminology), the event domain and the nominal domain are mediated by thematic roles. Thematic relations that bear graduality (GRAD) establish a homomorphism between the event-structure and the NP-denotation, saying that parts of the event relate to parts of the object and vice versa. It can then be shown that a noun phrase projects its reference property to the VP under non-iterativity; a quantized object induces a quantized VP (telic) and a cumulative object induces a cumulative VP (atelic). Furthermore the actualization step is straightforward as it is defined by a homomorphism from events into time intervals. Non-iterativity is defined by the negation of ITER in (4) which says that a thematic relation R is iterative with respect to (a subpart of) x within event e.

(4) $\text{ITER}(e,x,R) \text{ iff } R(e,x) \wedge \exists e',e'' \, \exists x' \; [e' \leq e \wedge e'' \leq e \wedge e' \neq e'' \wedge x' \leq x \wedge R(e',x') \wedge R(e'',x')]$

4. Lifting terminativity to a reference property

It is certainly possible to lift Verkuyl's proposal to the level of reference properties, maintaining the predictions. Simply redefine Verkuyl's definition of terminativity in terms of an upperbound: (5a) says that a path p is bounded iff there is a least upperbound on the number of collections associated with the locations. For completeness the definition of a least upperbound is given in (5b). Note furthermore that the measure function of cardinality in (5a) imposes a partial ordering on the set $\{p(n) \mid n \in \mathbf{N}\}$.

(5) a. p is bounded iff there is a $m \in \mathbf{N}$ with $\text{LUB}(m, \{|p(n)| : n \in \mathbf{N}\})$

b. y is a least upperbound for a partially ordered set X: LUB(y,X) iff $\text{UB}(y,X) \wedge \forall z\,[\text{UB}(z,X) \rightarrow y \leq z]$

Where y is an upperbound for X: UB(y,X) iff $\forall x \in X : x \leq y$

A definition in terms of an upperbound characterizes Verkuyl's theory equally well and it is particularly suitable if one is interested in lifting the definition of terminativity to the level of descriptions as in (6a): a set of paths is bounded iff there is an upperbound on the number of locations. At the level of descriptions there is no need to have infinite path structures, therefore a type for Finite Paths is introduced in (6b). Note that the set of paths X is partially ordered by length[7] (6c) which counts the number of locations in a path.

(6) a. A set of Finite Paths X is bounded iff
$\exists m \in \mathbf{N}\ \mathrm{LUB}(m, \{\mathrm{length}(p) \mid p \in X\})$

b. The function space of Finite Paths FP contains all (and only) functions p into Coll^+ with $\mathrm{dom}(p) \subseteq \mathbf{N}$, dom(p) finite and convex (i.e. continuous), and $\min(\mathrm{dom}(p))=1$.

Coll^+ is the function space of collections except for the empty collection: $\mathrm{Coll}^+ := \mathrm{Type}\ (d,t) — \varnothing$

c. For $p \in \mathrm{FP}$: $\mathrm{length}(p) := |\mathrm{dom}(p)|$

Also in the nominal domain the notion of boundedness readily applies. A set of collections X is bounded iff there is a least upperbound on the cardinality of the collections (7).

(7) X is bounded iff $\exists m \in \mathbf{N}\ \mathrm{LUB}(m, \{|Y| : Y \in X\})$

Assuming that the noun set associated with the NP is infinite, not fixed in advance, the non-increasing predicative NPs are bounded under (7), whereas the increasing ones are unbounded. To show that the predictions of Verkuyl's theory are preserved we calculate the meaning of the VP by (8), thereby spreading collections in a cumulative way over the locations of the paths.

(8) Given that NP denotes a set of collections and V a set of Finite Paths,[V+NP] translates as:
$\{p \in \mathrm{FP} \mid V(p) \wedge \exists X\ \mathrm{NP}(X) \wedge X = \cup\mathrm{rng}(p) \wedge \text{non-iterative}(p)\}$

(9) $\text{non-iterative}(p)$ iff $\forall n,m \in \mathrm{dom}(p)\ [n \neq m \rightarrow [p(n) \cap p(m) = \varnothing]]$

In this 'lifted' setting the restriction of non-iterativity in (9) is somewhat stronger than the requirement that rng(p) is a partition. The reason is that a mere partition requirement neglects the token-dependency of collections and therefore cannot distinguish between identical collections assigned to different locations. This incapacity to differentiate then creates an unforseen escape-hatch for terminativity. Consider for example a path p with one location related to a collection $\{x\}$. Extend this path to a path p' by adding a location which is related to the same collection $\{x\}$. The two instances of $\{x\}$ will collapse in the range of the path: rng(p)=rng(p'). Thus the requirement that the range of the path should be a partition cannot prohibit that paths are extended by adding identical collections. Consequently there cannot be a bound on the length of the paths in the denotation of a description. Definition (9) repairs for this problem and as a consequence we get the following interesting theorems which are reminiscent of Verkuyl's informal feature algebra.

(10) If [| NP |] is bounded then [| V+NP |] is bounded.
If [| NP |] is unbounded then [| V+NP |] is unbounded.

From (10) it is seen easily that the predictions (including the false predictions) of Verkuyl's theory are preserved. Infinite collections or infinite paths are not necessary. Furthermore the mapping from event structure to temporal structure need not depend on the presence of a culmination point; it is just enough to require that the interval assigned to some location properly extends the interval assigned to its predecessor. This latter feature obviates the need to distinguish between the notion of *proto-event*, used by Verkuyl to refer to the path (the possibly forever lasting event at some conceptual level), and Verkuyl's notion of *event*, the part of the path that is actualized. Crucially every part of the path is actualized.

There are three questions left that have to be answered with respect to this lifted setting. First, the interesting thing of boundedness is that while every finite set is bounded intrinsically, not every infinite set is unbounded. Thus (un)boundedness makes sense only for infinite domains (which is not to say that it cannot apply to finite domains). The question that arises however is whether this implies having infinite NP and VP denotations. Second, there is still a gap between Krifka's lattice-theoretical event structure and Verkuyl's paths. Can it be overcome? Third, how does Krifka's proposal relate to the concept of infinity?

4.1 *The source of infinity: natural culmination as necessary termination*

As to the first question let us consider the source of the infinity. Crucial to this discussion is the distinction between the termination of an event that is inherent in its description (culmination) and the termination of an event due to the world knowledge that events do not continue forever. The noun set, verb set and VP set are kept infinite to ensure that the paths/events in the denotation of a description like *read two books* will not be bounded in a trivial sense, namely due to the introduction of an arbitrary cut-off point on the domain of interpretation. In a given situation, with a fixed domain of interpretation, any event will be bounded to the extent that it will terminate at a certain point in time. However, what is crucial for the determination of a natural culmination point is not just that an event terminates, but that it terminates *necessarily* because a certain result that is inherent in the description has been reached. In fact what is modelled by the infinite domain of interpretation then is the idea that the presence of a natural culmination point can be determined only if one knows the meaning of a description in infinitely many situations. It is this discrepancy between termination on the one hand and culmination on the other that Verkuyl tries to model by making a principled distinction between a proto-event and its actualization in a certain situation. I argue however that this distinction must not reside in the mapping from the event structure to the temporal structure and that it is better accounted for in terms of a reference property.

To exemplify this point consider an event of *read two books*. A natural culmination point does *not* come about because in a given situation the event terminates after the second book has been read; rather it comes about because in all other imaginable situations an event in the denotation of *read two books* terminates after the second book.

We model this approach in terms of possible worlds. Boundedness then is defined as an abstraction over possible worlds. Definition (11) allows one to have finite NP and VP denotations per world/situation. The construction of the VP is redefined accordingly in (12). It constructs for every world w the set of paths associated with the VP:

(11) a. Given that w is the type of worlds and p the type of Finite Paths,P of type (w,(p,t)) is bounded iff
$\exists m \in \mathbf{N}\ \mathrm{LUB}(m, \{\mathrm{length}(p) \mid \exists w\ P(w)(p)\})$

b. P of type (w,(d,t)) is bounded iff
$\exists m \in \mathbf{N}\ \mathrm{LUB}(m,\{|X| : \exists w\ P(w)(X)\})$

(12) $\lambda w\lambda p.\ V(w)(p) \wedge \exists X\ NP(w)(X) \wedge X{=}\cup\ \mathrm{rng}(p) \wedge \text{non-iterative}(p)$

4.2 *Relating Verkuyl's paths and Krifka's events*

The second question addresses the issue of whether Verkuyl's path structure and Krifka's event structure can be generalized over. Whatever the answer to this question may be, it turns out that paths give rise to some technical problems. First, in general the information contained in a path is not sufficient to identify an event. In the present setting we cannot distinguish between two cooccurring events with the same internal structure. Second, and related to the first problem, is that by adopting the notion of a path a type distinction is made between superevents (the path as a whole, a function) and subevents (a location, a natural number), while it is hard to see what is gained from making such a distinction (both theoretically and empirically). The two problems can be overcome at once under the constructional definition of a path in (13).

(13) a. The space of basic paths BP are all those functions f into $Coll^+$ with $dom(f) = \{e\}$ for $e \in E$. Where E is an unordered set of atomic events/indices.

b. The set of (complex) paths PT is the minimal set s.t.:
- $BP \subseteq PT$
- For $f \in PT$ and $g \in BP$, if $Act(f) < Act(g)$ and $Act(f \cup g)$ is convex, then $f \cup g \in PT$

c. Actualization, a mapping from PT into intervals, is a homomorphism:[8]
$Act(f \cup g) = Act(f) \cup Act(g)$

Under this definition a path is constructed out of a number of basic paths. A basic path is a relation between an event-index and a collection. Complex paths come about as the result of a restricted closure operation on basic paths: only paths whose actualization satisfies the right conditions may be taken together. It then turns out that a constructional approach to the path structure can be readily compared to Krifka's event structure. To see this, note that Krifka accounts for the bond between events and collections in terms of thematic relations which map events onto collections. According to Krifka themes bear summativity, which says that a thematic relation R undergoes closure under summation for two-place relations:

(14) $SUMM(R)$ iff $[R(e,x) \wedge R(e',x')] \rightarrow R(e \oplus e',x \oplus x')$

On a closer inspection SUMM has the same effect as the summing of two path functions ($f \cup g$). An essential difference however is that summativity discards the token-dependency of collections; at the level of superevents ($e \oplus e'$) one cannot tell which parts of the object $x \oplus x'$ correspond to which subevents (e and e'). Furthermore, as $\oplus$ is idempotent (i.e. $x \oplus x = x$, compare $\{x\}\cup\{x\} = \{x\}$) at the level of superevents one cannot distinguish between identical collections that are assigned to different subevents. In our lifted setting this behavior may be readily compared to the requirement $X=\cup rng(p)$, by which means the range of the path flattens once V and NP merge.

Thus far, however, it is impossible to treat Verkuyl's paths in terms of thematic relations, since the condition of non-iterativity is not captured by SUMM. Thus the question arises whether *non-iterative(p)* could derive from some other properties of thematic relations. For this purpose Krifka's ITER, seen in (4), can be used. Given the VP-scheme in (15), SUMM(R) ensures that collection x is spread in a cumulative way over the subevents of e and $\neg ITER(R,e,x)$, in turn, ensures that no subcollection of x occurs in e more than once.

(15) $\lambda e\ V(e) \wedge \exists x\ NP(x) \wedge R(e,x)$

There is one case left that has to be ruled out however. In principle one event can relate to two or more collections simultaneously since R is a relation, not a function. In Verkuyl's setting this option is ruled out by the claim that two adjacent locations may differ in at most one collection. In Krifka's system this condition is met by *uniqueness of objects* (UNI-O) which is integral to the definition of gradual thematic relations (GRAD).

(16) $\text{UNI-O(R) iff } [R(e,x) \wedge R(e,x')] \rightarrow x=x'$

These assumptions then suffice to show that paths and thematic relations are to a large extent mutually definable. Boundedness may be defined in an event-based setting. (17a) says that a set of events is bounded iff there is a least upperbound on the length of the events, whereby the length of an event (17b) is the number of atomic events it is composed of.

(17) a. A set of events E is bounded iff $\exists m \in \mathbf{N}\ \text{LUB}(m, \{\text{length}(e) \mid e \in E\})$
b. $\text{Length}(e) := |\{e' \mid e' \leq e \wedge \neg\exists e''\ e'' < e'\}|$

Given that the denotation of Vs, NPs and VPs are not fixed in advance, the same theorems as in (10) are obtained for the VP-scheme in (15) if R bears SUMM, non-iterativity in the sense of ITER and UNI-O.

4.3 *Reference properties as an abstraction over worlds*

Finally, to arrive at a true unification, the constructs *quantized*, *cumulative* and *bounded* should be relativized to possible worlds. At first sight this may seem to be a generalization to the worst case, but it turns out that Krifka's system benefits from such a shift as well. In this respect it can be observed that QUA and CUM are not mutually exclusive. There are two problematic cases. First, a uniquely referring expression like *Mary* that is intuitively quantized comes out both cumulative and quantized. Second; a bare plural like *books* that intuitively is characterized as cumulative, comes out both quantized and cumulative in a situation with only one book. And the same holds for *walk* (atelic) in a situation with only one event of walking.

A solution to these cases is to replace CUM by *strictly cumulative* (18a) and to define *quantized* and *strictly cumulative* as necessary properties, as in (18b). Under (18b) *Mary* cannot be strictly cumulative[9] (SCUM') and *books/walk* cannot be quantized (QUA'), since it is not quantized in all possible situations.

(18) a. $\mathrm{SCUM}(P)$ iff $\mathrm{CUM}(P) \wedge \neg\mathrm{QUA}(P)$
b. For P of type (w,((d,t),t)) or (w,(e,t)):
$\mathrm{QUA'}(P)$ iff $\forall w\ \mathrm{QUA}(P(w))$
$\mathrm{SCUM'}(P)$ iff $\forall w\ \mathrm{CUM}(P(w)) \wedge \neg\mathrm{QUA}(P(w))$

Scheme (15) should be changed accordingly to (19a). Thematic relations are then defined as relations that given a world w map events onto objects. Thus properties of thematic relations are easily adapted by making them into necessary properties; (19b) may serve as an example. VP-boundedness, in turn, is defined as an abstraction over worlds in (19c).

(19) a. $\lambda w \lambda e.\ V(w)(e) \wedge \exists x\ NP(w)(x) \wedge R(w)(e,x)$
b. $\mathrm{SUMM'}(R)$ iff $\forall w\ \mathrm{SUMM}(R(w))$
c. For P of type (w,(e,t)):
$\mathrm{Bounded}(P)$ iff $\exists m \in \mathbf{N}\ \mathrm{LUB}(m, \{\mathrm{length}(e) \mid \exists w\ P(w)(e)\})$

5. Comparison of Verkuyl and Krifka at the level of descriptions

As is apparent from the discussion so far, Verkuyl's bounded-unbounded opposition makes predictions that are very similar to Krifka's quantized-cumulative opposition. This provokes the question which construct is to be preferred empirically. There is no easy answer to this question, except that neither opposition can easily account for the fact that bare plurals induce durativity and monotonically increasing NPs that somehow carry a cardinality specification, induce terminativity. Apart from this the question arises to what extent bounded/unbounded is similar to quantized/cumulative if we abstract away from the question of which denotations are actually realized in natural language.

In the nominal domain it turns out that a (strictly) cumulative NP need not be unbounded. Consider the case where we have $[\![NP(w)]\!] = \{\{a\},\{b\},\{a\} \cup \{b\}\}$ for every world w. Neither does the converse hold. An unbounded NP need not be cumulative. Consider a set $X = \{Y \mid \exists w\ NP(w)(Y)\}$ which is unbounded and simply cut out some collections in some world w' s.t. $\neg\mathrm{CUM}(NP(w'))$. This change will be seen by X, but still X will be unbounded.

As for the bounded-quantized opposition it turns out that a bounded NP need not be quantized. Consider again the case where $[\![NP(w)]\!] = \{\{a\},\{b\},\{a,b\}\}$ for every w. For the other direction it suffices that a partition of an infinite set may be unbounded. As the cells of the partition do not overlap, the partition will not contain a collection and a subcollection thereof simultaneously. Hence a quantized NP need not be bounded.

In the event domain similar results obtain. For the cases given above simply interchange collections and events whereby set-union is mapped on ⊕. For the partition case note that cells of the partition are made up of sequences of events combined by ⊕, e.g. e ⊕ e' ⊕ e''. So, for an infinite set of atomic events an unbounded partition exists such that the sequences in it do not overlap in terms of 'being composed out of the same atoms'.

6. Conclusion

Although the theories of Verkuyl and Krifka differ sharply at the formal level it can be shown that they can be unified to a large extent by lifting Verkuyl's theory to the level of descriptions. This move has some nice consequences. First, some technical problems that had to be dealt with in Verkuyl's theory are solved. Second, the predictions of Verkuyl's theory are preserved, suggesting that the theory is neutral with respect to the question whether boundedness should be a reference property or not. Third, although at first sight path structures and event structures may seem to be of a quite different nature, it turns out that paths and thematic relations on events are to a large extent mutually definable. Thus the lifted framework can be readily compared to Krifka's system in terms of formal properties. It then turns out that also from a formal point of view (as opposed to an impressionistic point of view) Verkuyl and Krifka share the same assumptions about the mapping between the nominal domain and the event domain; collections are associated with the event-structure in a cumulative way and to let reference properties project an appeal is made to non-iterativity.

Although a unification is not feasible in that (un)boundedness at most overlaps partially with cumulative/quantized, a general framework for aspectual composition is obtained in which different reference properties can be studied.

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Notes

1. In the discussion we neglect the partake operation on P that 'X-rays' collections of P for members of the noun set (cf. Verkuyl 1993 and Van der Does 1992).
2. Although in (1) functional operations and set-theoretical operations are mixed up, this 'sugared' way of writing up formulas greatly increases readibility. There is no harm in doing so, since characteristic functions are readily type casted to sets and vice versa: for f of type (x,t) the set associated with f is $\{x \mid f(x)=1\}$, and for a set X with members of type x the function associated with it, is the function f of type (x,t) such that $f(x)=1$ if $x \in X$, otherwise $f(x)=0$. Throughout the paper these type-casting operations are left implicit. Furthermore it is assumed that sets and operations on sets are part of the logical language.
3. It might be important to note that [±SQA] is defined on empirical grounds: NPs that induce durativity are [–SQA] and NPs that induce terminativity are [+SQA]. Semantically speaking it is difficult to distinghuish between collections that have a cardinality specification and collections that lack such a specification; it simply cannot be denied that sets have a cardinality.
4. Type 'e' is reserved for the type of events.
5. Note by the way that the requirement of introducing an infinite set is a necessary condition, but not a sufficient condition for escaping terminativity. The reason is that terminativity under this definition is sensitive to the number of cells in the partition. Still a partition of an infinite set may consists of finitely many cells.
6. Although strictly speaking a set of collections confined to members of the noun set, cannot be said to be increasing or decreasing in the same sense as a generalized quantifier is, there is a straightforward relation between the monotonicity of a generalized quantifier and the monotonicity of a predicative interpretation associated with it:
   (i) For D(N) Mon$\uparrow$, the predicative $\{X \mid D(N)(X) \wedge X \subseteq N\}$ is N-mon$\uparrow$.
   For D(N) Mon$\downarrow$, the predicative $\{X \mid D(N)(X) \wedge X \subseteq N\}$ is N-mon$\downarrow$.
   For non-monotonous D(N), $\{X \mid D(N)(X) \wedge X \subseteq N\}$ is neither N-mon$\uparrow$ nor N-mon$\downarrow$.
   (ii) A set of collections X is:
   - N-mon$\uparrow$ iff $\forall Y,Z \subseteq N\ Y \subseteq Z \Rightarrow Y \in X \rightarrow Z \in X$
   - N-mon$\downarrow$ iff $\forall Y,Z \subseteq N\ Z \subseteq Y \Rightarrow Y \in X \rightarrow Z \in X$
7. This use of the term *length* should not be confused with the stretch of time associated with a path; in the temporal domain a path of length 1 may be larger than a path of length 5.
8. Presumably an additional requirement is necessary: basic paths with the same domain are associated to the same interval, i.e. $\forall p,p' \in BP\ [dom(p)=dom(p') \rightarrow Act(p)=Act(p')]$.
9. Although SCUM could also be defined without a reference to possible worlds, in an extensional setting SCUM cannot be taken to define the general notions of 'absence of a natural culmination point' and 'unspecified cardinality'. Instead of adopting SCUM, Krifka adheres to the weaker CUM and refers only to SCUM to deal with the problematic cases.

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