Countability in the Nominal and Verbal Domains

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Advanced Course

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Empirical motivation: Mereological event semantics

- A longstanding observation that both nouns and verbs have the feature MASS or COUNT.

  Early studies: Allen 1966, Leech 1969, Gabbay and Moravcsik 1973, Bolinger 1975, Taylor 1977, Mourelatos 1978; Hoepelman and Rohrer 1980, L. Carlson 1981, Verkuyl 1971/72 (and elsewhere), among others.

- One piece of evidence: Nouns and verbs pattern alike with respect to expressions denoting numbers or amounts: COUNT : MASS = TELIC : ATELIC.

MASS	ATELIC
Much mud was in evidence.	John slept a lot last night.
(*) Much dog was in evidence.	(*) John found a unicorn a lot last night.
COUNT	TELIC
Many dogs were in the yard.	John fell asleep 3 times during the night.
(*) Many muds were on the floor.	(*) John slept 3 times last night.

Bach 1986

Telic verb denotations "can be directly or intrinsically counted" (...) they "fall under SORTS that provide a PRINCIPLE of count" (Mourelatos 1978, p. 429-30). Atelic verb denotations lack this property.

Dog is a sortal and *mud* is not, similarly, *fall asleep* is a sortal and *sleep* is not.

Mereological Event Semantics:
Bach's (1986) programmatic approach outlined in "The Algebra of Events"

Mereological Event Semantics: Bach (1986) "The Algebra of Events"

- **Main innovation**: Extending Link's (1983) lattice-theoretic analysis of mass terms and plurals to verbs to model the semantics of telic and atelic aspectual classes.

  Formal analysis of the direct structural analogy MASS : COUNT = ATELIC : TELIC.

- **Background: Neo-Davidsonian event semantics**
  - Nouns express predicates of objects: λx[noun'(x)]. (NPs are indefinite descriptions of objects.)
  - Verbs express one-place predicates of EVENTUALITIES: λe[verb'(e)]. Verbs denote an eventuality type (a set of eventualities). (Sentences are indefinite descriptions of eventualities, see Davidson 1967).

    "Eventuality" (Bach's 1981 term) covers not only the denotations of predicates denoting actions or events in the sense of Davidson (1967, 1969 and elsewhere), but also predicates that denote states.

❖ Both nouns and verbs denote sets. This facilitates the statement of generalizations across the nominal and verbal domain.

- Additional commitments of Neo-Davidsonian event semantics

  – Verbs introduce an eventuality argument into the logical structure of predicates:
  λyλxλe [HUG(e) ∧ AGENT(e,x) ∧ THEME(e,y)]: 'a set of events of x hugging y'.

  – The eventuality argument in the logical structure of sentences is existentially quantified:
  ∃e[HUG (e) ∧ AGENT (e, john) ∧ THEME (e, mary)] "An event of John hugging Mary."
  This implies that sentences are indefinite descriptions of eventualities (Davidson 1967).

  – Objects and eventualities are fundamental ontological categories (Davidson 1967).
  Eventualities are particulars (Davidson 1967), just like ordinary objects, they can be

    - mapped to space-time locations (albeit in different ways, see Davidson 1980, pp.176):
    John hugged Mary for five minutes straight at midnight on the street.
    Caveat: Events cannot be reduced to or individuated with respect to spacetime locations (Davidson 1980, p.178)
    - anaphorically referred to by pronouns: *John hugged Mary and Bill saw it (*= the event of John hugging Mary).

  – The modifiers are predicates of the event argument and added conjunctively. The event argument serves as a "hook" to tie together modifiers with the predicate they modify.

Classification of (predicates of) eventualities into aspectual classes

- Each verbal predicate denotes an eventuality type (a set of eventualities) that is classified into one of the aspectual classes: $\mathcal{E} = S \cup P \cup E$

Bach 1981, 1986; Parsons 1990
alternative classification of Vendler 1957; Dowty 1972, 1979

EVENTUALITIES					
STATES		non-states			
dynamic	static	**PROCESSES**	**EVENTS**		
			protracted	momentaneous	
				culminations	happenings
sit, stand, lie+LOC	*be drunk* *be in New York* *own x, love x* *resemble x*	*walk* *push a cart* *be mean* (AG)	*build x* *walk to Boston*	*die* *reach the top* *arrive*	*recognize* *notice* *flash once*
state		activity	accomplishment	achievement	
ATELIC			TELIC		Garey 1957

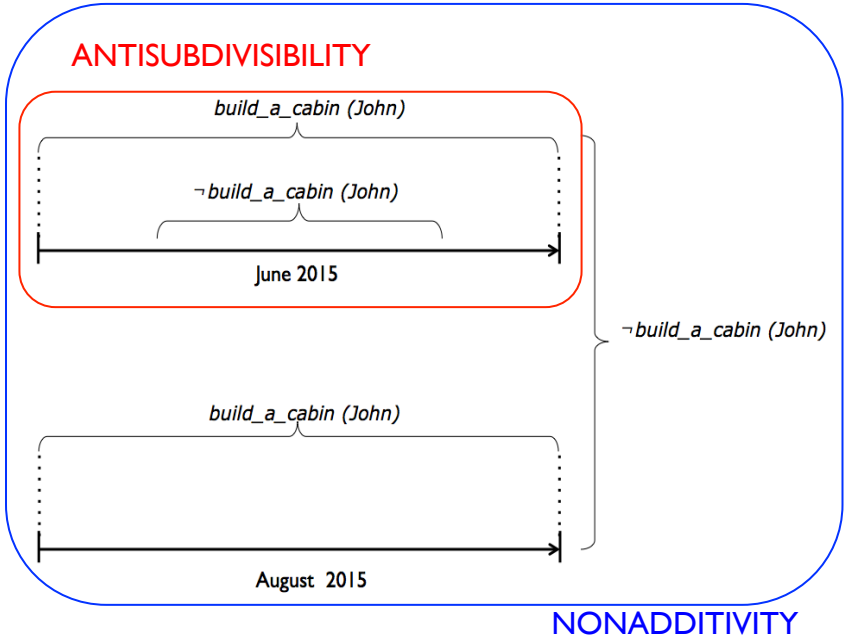
Mereological properties of EVENT (telic) and PROCESS (atelic) predicates (Bach 1981)

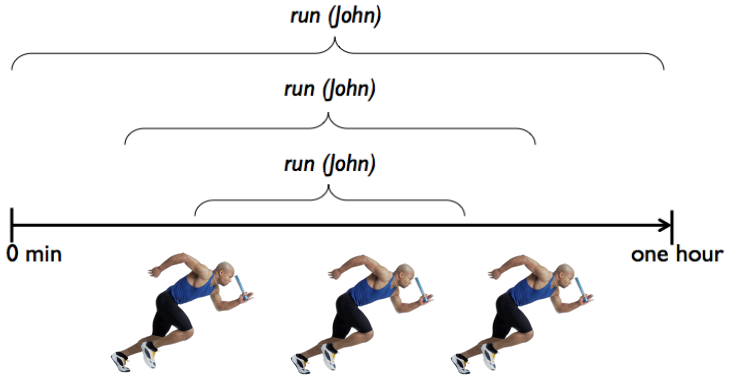
EVENT predicates (*build a cabin*, *die*, *arrive*) just like singular count nouns (*dog*) are

- *antisubdivisible* (no proper part of one event can be an event of the same kind), and
- *nonadditive* (the sum of two distinct events of the same kind is never an event of the same kind).

PROCESS predicates (*run, swim)* just like mass terms (*water*) and bare plurals (*apples*)

- lack the property of antisubdivisibility and nonadditivity.

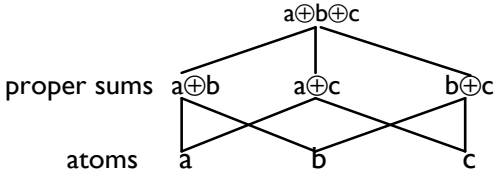




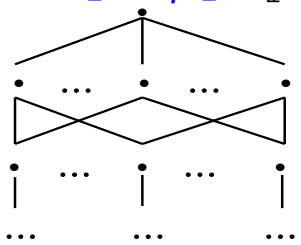
Two-sorted domain for predicates of EVENT and PROCESS eventualities (Bach 1986)

- Assuming that verbs (express one-place predicates that) denote sets of eventualities, such sets have the algebraic structure of complete join semilattices, partially ordered by the mereological part relation '≤' (Bach 1986).
- Two-sorted domain of eventualities, in parallel to Link's (1983) two-sorted domain of objects:

⟦ *arrive* ⟧ ≈ ⟦ *apple/s* ⟧



⟦ *sleep* ⟧ ≈ ⟦ *water* ⟧



EVENT verbs like *arrive, die, win* take their denotation from the domain structured by means of an atomic join semilattice, just like the denotation of a COUNT noun like *apple*. The 'minimal' events denoted by verbal predicates are the atoms like individual apples, the 'non-minimal' eventualities are the non-atomic elements (sum eventualities), like pluralities of apples.

PROCESS verbs like *sleep, run, swim* take their denotation from a non-atomic domain, just like the denotation of a MASS noun like *water*. (summary Partee 1999)

❖ The 'direct or intrinsic countability' of telic predicates (Mourelatos 1978, p.429-30, i.a.) is modeled by the atomicity of their domain.

A programmatic proposal for a unified lattice-theoretic treatment (Bach 1986)

for a number of phenomena linking the mass/count and process/event distinctions:

- Cooccurrence patterns with various expressions of number and quantity:

MASS	ATELIC
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COUNT	TELIC
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Bach 1986

- Measure constructions with noun and verb predicates.
- Packaging and grinding: sort-shifting (type-shifting) operations with nouns and verbs.
- Partitive puzzle: the part relation in the nominal domain and the progressive operator in the verbal domain.

Measure constructions with noun and verb predicates

- Nominal measure terms (*a pound of*) and durational *for* α-time adverbial modifiers (*for ten minutes*) are both restricted to select for cumulative *P*s.

Nominal measure NP (pseudopartitive)	*a kilo of sugar* *a kilo of oranges*	**a kilo of a pound of sugar* **a kilo of a thousand grams of sugar* **a kilo of a pound of oranges* **a pound of a horse*
Durational ***for*** **α**-time	*John ran for ten minutes.*	**John ran a mile for ten minutes.* *?? I found a penny for ten minutes.*

- Bach (1981, p.74): "The combination of a specific durational adverbial with a process (atelic) predicate (or sentence) acts in every way like an event (telic) predicate (or sentence) (...) Durational expressions stand to verbal expressions as amount expressions stand to nominal expressions. Just as we do not use expressions like *3 pounds of* with singular count nouns like *a horse*, we do not use the expressions that chunk up our experience with (singular) expressions that provide that experience already chunked up."

Food for thought:
Every ounce of a pound of sugar weighs 1/16 of the total.

Packaging and grinding: coercion operations with nouns and verbs

Count-to-mass via the "Universal Grinder" (Pelletier 1975/1979, David Lewis, pc).

(1) *There is apple in the salad.*
The mass syntax triggers a shift of the inherently count term *apple* into a mass term which refers to the stuff apples consist of.

Event-to-process:

(2) *The worm ate the apple bit by bit for an hour.* *for* α-time: STATE ∪ PROCESS → EVENT

Mass-to-count via the "Universal Packager" (Bach 1986)

(3) *She prefers Tuscan wines.* [= kinds of Tuscan wine]
(4) *After two beers, he's incoherent.* [= servings of beer]
(5) *We ordered three wines, by the glass, one white and two reds at varying price points.* [= kinds and servings of wine]

Process-to-event

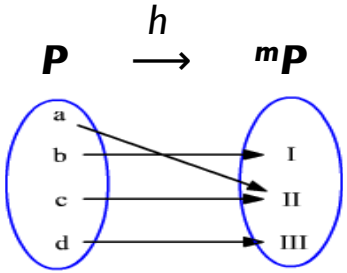
(6) *Today, John swam in an hour.*
(i) John swam a certain contextually specified distance in an hour (Dowty 1979, p.61)
(ii) John started swimming after an hour (from some contextually specified ref. time)
(some native speakers find (i) and (ii) difficult to accept)

Asymmetry in coercion operations

- Packaging (*two beers, John ran in an hour*):
  Meaning changes associated with non-count to count coercion are much less systematic (and require more work on the part of the interpreter) than those associated with the grinding coercion operation.

  > "A beer may be a serving of beer or a kind of beer. Similarly, in the verbal domain, when we put a process expression into a count context, we must come up with some kind of corresponding event, but just what it is is relatively free, perhaps the beginning of the process in question, or some bounded portion of it (Bach 1986. p.11).

- Motivation: Link's (1998:27/(59) materialization function ***h***:



h "is a function (homomorphism) from the count elements to the non-count ones, but it is a many-to-one mapping so that we can't in general expect a unique answer when we ask what count element this portion of non-count stuff might correspond to" (Bach 1986:11).

Partitive puzzle

(1) a. Mozart was composing the Requiem when he died. PROG(P) incomplete events
b. Mozart composed the Requiem. P

(2) a. This is part of a bridge. PART(P) incomplete objects
b. This is a bridge. P

A part of a bridge called "The Bridge of Avignon": there used to be a whole bridge that once crossed the Rhone, but a part of it was destroyed and has not been rebuilt.

- The truth conditions for the progressive and the parallel nominal "part of" construction would seem to require that there be a (whole) *P* to which some *e* or *x* (respectively) stands in a part-whole relation:

PART = $\lambda P \lambda x' \exists x[P(x) \wedge x' \leq x]$
PROG = $\lambda P \lambda e' \exists e[P(e) \wedge e' \leq e]$ Krifka 1992a, p.47

❖ The main – still outstanding – puzzle and challenge is to specify the relation between the denotations of partial/incomplete objects and events and their corresponding complete (intensional) counterparts.

Krifka (1986-present): Mereological event semantics and aspectual composition

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- **One Domain approach**

  Parsons 1990 (suggestions in Bach 1981, p.69; Link 1987) i.a. : eventualities like PROCESS or EVENT are 'nonlinguistic things in the world'

  drink wine - *drink a glass of wine*: Is there a sortal difference in the ontological nature of what is described with *drink wine* and the same situation described with *drink a glass of wine* or *drink wine from a glass*?

- Krifka (1986, 1989, 1998): Similarly as with nouns, no essential distinction between atomic and non-atomic domain for the denotations of verbal predicates (*pace* Bach 1986, Link 1987, Parsons 1990).
- **Reason**: What is 'out there' in the real world is individuable under particular descriptions, different descriptions ascribe different properties to them (see Davidson 1969, Krifka 1989, 1998, Filip 1993/99, Partee 1999, Rothstein 2004, i.a.).
- The classification under categories like TELIC (EVENTS) or ATELIC (PROCESSES), QUANTIZED or CUMULATIVE concern predicates of eventualities, not eventualities 'in the world', they are properties of eventuality descriptions, or of eventualities under a particular description.
- TELIC, ATELIC, PROCESS, EVENT, CUMULATIVE, QUANTIZED, etc. are second-order properties of predicate ('it makes no sense to speak of 'telic events' and the like', Krifka 1998, p. 207).

Mereological properties of basic lexical episodic verbs

Bach 1981, 1986; Parsons 1990
Vendler 1957; Dowty 1972, 1979

<table>
<tr><td colspan="6">EVENTUALITIES</td></tr>
<tr><td colspan="2">STATES</td><td colspan="4">non-states</td></tr>
<tr><td>dynamic</td><td>static</td><td>PROCESSES</td><td colspan="3">EVENTS</td></tr>
<tr><td></td><td></td><td></td><td>protracted</td><td colspan="2">momentaneous</td></tr>
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<tr><td>sit, stand, lie+LOC</td><td>be drunk
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own x, love x
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be mean (AG)</td><td>build x
walk to Boston</td><td>die
reach the top
arrive</td><td>recognize
notice
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- structural analogy 'mass : count = process : event'

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- structural analogy 'mass : count = process : event' concerns mereological properties of basic lexical items
- In English (and other Germanic languages),
  - accomplishments (Vendler-Dowty terminology) or
  - protracted events (Bach-Parsons terminology)

  are not expressed by basic lexical verbs, but instead by predicates that are syntactically constructed at the level of *VP* (Kratzer 2004) and also a sentence (Filip & Rothstein 2005; Filip 2008, Rappaport Hovav & Levin 2008; Krifka 1998, i.a.).

Mereological properties of basic lexical episodic verbs

CUMULATIVITY

CUMULATIVE(P) $=_{def}$ $\forall e, e' [P(e) \wedge P(e') \rightarrow P(e \oplus e')] \wedge \exists e \exists e' [P(e) \wedge P(e') \wedge e \neq e']$
Krifka 1986, 2013 and elsewhere.

– Predicates of events: *arrive, die, recover, recognize, notice, flash* ***once*** ...
If e, e' fall under *arrive (once),* then e⊕e' falls under *arrive* ***twice***, ...

– Predicates of processes: *walk, push (a cart), run, rain, ...*
If e, e' fall under under *walk*, then e⊕e' may fall under *walk*, and not necessarily under *walk* ***twice***

– Bach (1981): additivity of PROCESS predicates

ATOMICITY, and hence QUANTIZATION

QUANTIZED(P) $=_{def}$ $\forall e, e' [P(e) \wedge e' < e \rightarrow \neg P(e')]$ Krifka 1986
If ATOM(e), then #(e) = 1; if ¬e⊗e', then #(e⊕e') = #(e) + #(e') Krifka 1989
'⊗': mereological overlap relation
'⊕': mereological sum operation
'#': the atomic number/counting function, a kind of (extensive) measure function

– Predicates of momentaneous events: *arrive, die, recover, recognize, notice, flash once ...*
If e is an event of arriving, then no proper part of e is an event of arriving.

– Bach (1981): antisubdivisibility of EVENT predicates

Mereological properties of basic lexical episodic verbs

- Predicates of MOMENTANEOUS EVENTS have a qualitative and a quantitative criterion of application:

  $[\![\textit{arrive}]\!] = \lambda e\ [\text{ARRIVE}(e) \wedge \#(e) = 1]$

  The quantitative criterion ("what is ONE in their denotation") is represented by means of the atomic number/counting function '#', which determines the atomic or singular non-overlapping events in their denotation:

- Predicates of PROCESSES only have a qualitative criterion of application:

  $[\![\textit{run}]\!] = \lambda e[\text{RUN}(e)]$

Distribution of the quantization and cumulativity properties across basic lexical Vs

- Basic lexical items: Count nouns correspond to verbs denoting momentaneous events, a subclass of Bach's (1986) EVENT class.

mass	$[\![water]\!] = \lambda x[\text{WATER}(x)]$
process	$[\![run]\!] = \lambda e[\text{RUN}(e)]$
count	$[\![apple]\!] = \lambda x\,[\text{APPLE}(x) \wedge \#(x) = 1]$
momentaneous event	$[\![arrive]\!] = \lambda e\,[\text{ARRIVE}(e) \wedge \#(e) = 1]$

- In English (and other Germanic languages), the class of native basic verbs that are atomic, and hence quantized, is small (compared to the rest of basic verb meanings); these are verbs that express predicates of MOMENTANEOUS EVENTS (Bach's (1986) terminology).

  The vast majority of native basic verbs is cumulative, they include predicates of PROCESSES (Bach's (1986) terminology).

  For related observations see Krifka 1998, Kratzer 2004, Filip & Rothstein 2005, Filip 2008, Rappaport Hovav & Levin 2008.

- In contrast, we do not seem to observe such an asymmetry between count and mass noun meanings in languages with a grammaticized mass/count distinction.

CONSEQUENCE: The vast majority of predicates that are quantized (telic) is morphologically or syntactically complex, where the requisite quantitative criterion of application is specified externally to the verb.

Krifka: From cumulative to quantized verbal predicates via measure functions

- Generally, the quantitative criterion of application for predicates ("what is ONE in their denotation") is represented by means of **measure functions**, a parallel strategy applied for the derivation of quantized predicates in the nominal and verbal domain.

- Various **extensive measure functions** are defined on a single domain of eventualities structured by a complete join semi-lattice which is undetermined with respect to atomicity.

- Predicates of MOMENTANEOUS EVENTS: atomic measure function '#' incorporated into the basic (root) verb, which motivates why they can be directly counted:

  $[\![\textit{arrive}]\!] = \lambda e\ [\text{ARRIVE}(e) \wedge \#(e) = 1]$
  $[\![\textit{arrive three times}]\!] = \lambda e\ [\text{ARRIVE}(e) \wedge \#(e) = 3]$

  ? sleep three times
  $[\![\textit{sleep}]\!] = \lambda e[\text{SLEEP}(e)]$

- For all the other quantized (telic) predicates, the measure function is specified externally to the basic (root) verb: e.g.,
  walk for three hours / a mile / to the pub
  eat three apples / a bowl of soup
  } ACCOMPLISHMENT

- The 'direct or intrinsic countability' of telic predicates (see Mourelatos 1978, p.429-30, i.a.) is not reducible to the atomicity of their denotational domain (pace Bach 1986).
  The essential property is quantization, and 'temporal quantization' as its special case.

Measure constructions with verbs

Bach's (1981, p.74) observation: "Durational expressions stand to verbal expressions as amount expressions stand to nominal expressions."

(1) a pound of sugar / *a book — measure f. over objects

(2) a. sleep for an hour / *eat an apple for an hour — measure f. over temporal traces of events
b. walk three miles / *arrive three miles — measure f. over path traces of events

Krifka's (1989) formal implementation

- Measure terms like *a pound of*
- durational adverbials like *for an hour*
- path measure NPs like *three miles*
  introduce an extensive measure function into the logical representation which is restricted to apply to cumulative predicates only: *sugar, sleep, walk*.
- Measure functions, such as those expressed by measure terms like *a pound of,* can be directly applied to objects, which have measurable dimensions like volume, extent:

  direct measurement of objects: $x \rightarrow \mu(x)$
  $[\![a\ pound\ of\ sugar]\!] = \lambda x[\text{SUGAR}(x) \wedge \text{POUND}(x) = 1]$, where POUND: measure function

- Measure functions can never be ***directly*** applied to eventualities, because eventualities can never be directly measured, because they have no measurable dimension as part of their ontological make up.

  Eventualities can be ***indirectly*** measured via their run times, distances in space, or some other measurable dimension (of participants) to which they are related (Krifka 1989; 1990, p.517-8). So we have:

direct measurement of objects: $x \rightarrow \mu(x)$

indirect measurement of eventualities via object-induced measures: $e \rightarrow h(e) \rightarrow \mu(h(e))$

h: free variable over homomorphism functions from the lattice of eventualities to the lattice of objects where μ is applicable: e.g., run times of eventualities, their associated paths, etc: e.g., temporal trace function τ, path trace function π

μ: free variable over measure functions: e.g., HOUR, MILE.

Krifka 1986, 1989, 1990 and elsewhere; Link 1987, Lasersohn 1995.

Temporal trace function τ: $E \rightarrow T$ Link 1987, Krifka 1989

$[\![$*walk for an hour*$]\!] = \lambda x,e[\text{WALK}(e) \wedge \text{AGENT}(e,x) \wedge \text{HOUR}(\tau(e)) = 1]$
In words: a set of sums of walking events to the amount of one hour.

- Intuitive idea: Temporal measure phrases like *for an hour* function as measures over run times (or temporal traces) of eventualities.

- Formal ingredients:
  $e \rightarrow \tau(e) \rightarrow \mu(\tau(e))$, where $\forall e,e'[\tau(e \oplus_E e') = \tau(e) \oplus_T \tau(e')]$
  τ is a homomorphism with respect to the sum operations for eventualities and times: The run time of the sum of two events *e, e'* is the sum of the run time of *e* and the run time of *e'*.

  τ (e) = t is the run time (or the temporal trace) of e
  $\mu(\tau(e))$, where μ is a free variable over measure functions that measures time like HOUR.

  hour as an extensive (additive) measure function for times: HOUR(t)=n
  hour transferred to events: $\text{HOUR}(\tau(e)) = n$

  application restricted to cumulative predicates, just like extensive (additive) measure functions over objects (e.g., *pound*):
  $[\![$*hour*$]\!] = \lambda P.\text{CUMULATIVE}(P)\ \lambda n \lambda e[P(e) \wedge \text{HOUR}(\tau(e)) = n]$
  $[\![$*pound*$]\!] = \lambda P.\text{CUMULATIVE}(P)\ \lambda n \lambda x[P(x) \wedge \text{POUND}(x) = n]$

Path trace function π: $E \rightarrow L$ Krifka 1989, 1990, p.517, 1998; Lasersohn 1995

$[\![$*walk three miles*$]\!] = \lambda x,e[\text{WALK}(e) \wedge \text{AGENT}(e,x) \wedge \text{MILE}(\pi(e)) = 3]$
In words: a set of sums of walking events to the amount of three miles.

- Intuitive idea: Spatial measure phrases like *three miles* function as measures over path traces of eventualities

- Formal ingredients:
  $e \rightarrow \pi(e) \rightarrow \mu(\pi(e))$, where $\forall e,e'[\pi(e \oplus Ee') = \pi(e) \oplus L\pi(e')]$
  A path trace function π is a homomorphism from eventualities *E* to locations/paths *L*, where the path trace of the sum of two eventualities e, e' is the sum of the path trace of e and the path trace of e'.

  $\pi(e) = l$ is the path trace of e.

  $\mu(\pi(e))$, where μ is a free variable over measure functions that measure distances in space, such as MILE.

Aspectual Composition: interactions between the mereological properties of nominal arguments and complex predicates

Aspectual Composition: Krifka (1989, 1992a, 1998)

Mereological properties of nominal arguments have an impact on mereological properties of complex verbal constructions – their quantized (telic) and cumulative (atelic) interpretation:

(1) aspectual composition	QUANTIZED: in ten minutes	CUMULATIVE: for ten minutes
a. Kim ate two/all the apples	√	*
b. Kim ate a bowl of soup	√	*
c. Kim ate apples/soup	*	√

(2) no aspectual composition		
a. Kim pushed two/all the carts / carts	*	√

Observations:

- Aspectual composition restricted to certain lexical classes of verbs: *eat* vs *push*.
- Atomicity does not guarantee quantization (telicity). *Eat apples* is cumulative, but *apples* denotes atoms and their sums.
- Non-atomicity does not guarantee cumulativity (atelicity). *Eat a bowl of soup* is quantized, but *a bowl of soup* would be treated as mass and non-atomic, all else being equal.

Previous relevant work: Garey 1957, Verkuyl 1971/72, Dowty 1972, 1979, Platzack 1979.

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- Aspectual composition restricted to certain lexical classes of verbs: *eat* vs *push*.
- Atomicity does not guarantee quantization (telicity). *Eat apples* is cumulative, but *apples* denotes atoms and their sums.
- Non-atomicity does not guarantee cumulativity (atelicity). *Eat a bowl of soup* is quantized, but *a bowl of soup* would be treated as mass and non-atomic, all else being equal.

Previous relevant work: Garey 1957, Verkuyl 1971/72, Dowty 1972, 1979, Platzack 1979.

PROPOSAL

STEP 1: Aspectual composition follows from the lexical semantics of certain episodic verbs.

These are verbs that have as a part of their meaning the entailment that there are systematic structure-preserving **object-event mappings** between the part structure (lattice structure) associated with their event argument and the part structure of the denotation of their (Strictly) Incremental Theme argument, which may be associated with various syntactic positions.

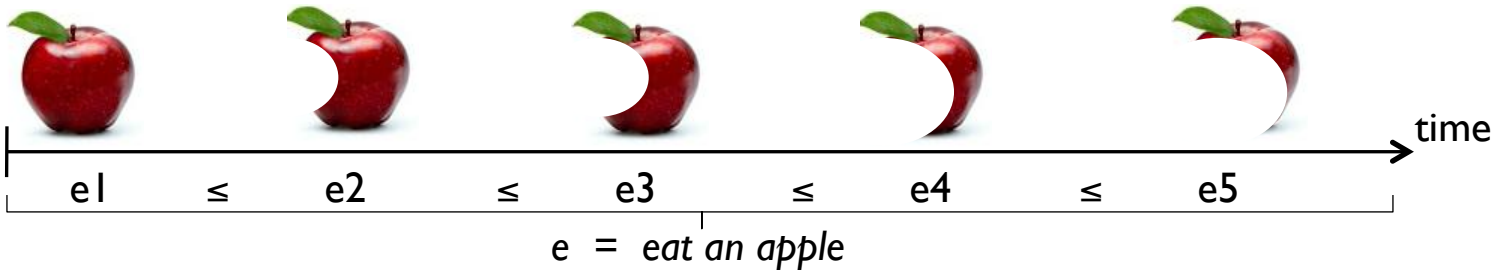
Such verbs are called

- INCREMENTAL verbs: *eat, drink, write, read, burn, destroy ...*
  lexically unspecified with respect to quantization/cumulativity (Filip 1993/99)

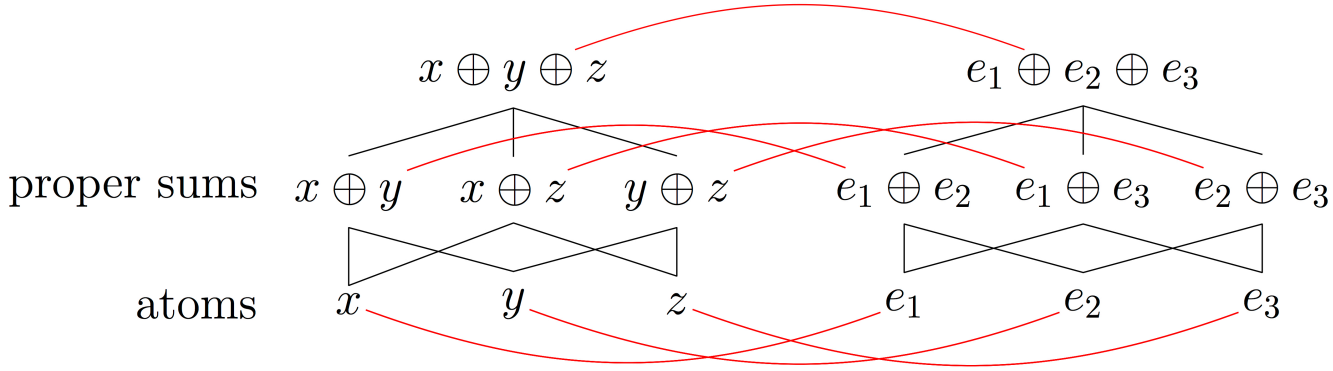
  Terminology: "Incremental Theme", coined by Dowty (1987, 1991) for "Gradual Patient" and "Successive Patient" originally used by Krifka (1986/89, 1992a).

Object-event mappings: *eat an apple*

Intuitive idea: Every part of an event of eating of one apple (e.g., a subevent of taking a bite from that apple) corresponds to exactly one proper part of that apple, and vice versa.



Lattice-theoretic representation of the structure-preserving mappings between the part structure of the denotation of *an apple* (= Incremental Theme) and the part structure associated with the denotation of *eat an apple*.



graphic representation Wechsler 1991

Object-event mappings: an entailment of incremental verbs

Cumulativity (summativity): $\forall R \forall e \forall e' \forall x \forall x' [R(e,x) \wedge R(e',x') \rightarrow R(e \oplus e', x \oplus x')]$
A general condition for participants of events; the 2-place version of cumulativity: e.g., two events e and e' of eating of an apple yield an event e⊕e' of eating of two apples.

i. *Uniqueness of Objects:*
There can be no two distinct objects which bear the thematic relation R to the same event.
$\forall R \forall e \forall x \forall x' [R(e,x) \wedge R(e,x') \rightarrow x=x']$

ii. *Uniqueness of Events:*
There can be no two distinct event which bear R to the same object.
$\forall R \forall e \forall e' \forall x [R(e,x) \wedge R(e',x) \rightarrow e = e']$

iii. *Mapping to Subobjects:*
If an event bears R to an object, any subpart of the event bears R to some subpart of the object.
$\forall R \forall e \forall e' \forall x \forall x' [R(e,x) \wedge e' < e \rightarrow \exists x'[x'<x \wedge R(e',x')]]$

iv. *Mapping to Subevents:*
If an event bears R to an object, any subpart of the object bears R to some subpart of the event.
$\forall R \forall e \forall e' \forall x \forall x'[R(e,x) \wedge x' < x \rightarrow \exists e'[e'<e \wedge R(e',x')]]$

v. *Strict Incrementality*:
If there are two distinct objects x and x', and two distinct events e and e' such that x<x' and e<e', then R(x,e) and R(x',e').

STEP 2: "Transfer of reference properties" of predicates: quantization and cumulativity

Aspectual composition straightforwardly follows from the structure-preserving mappings entailed by (strictly) incremental verbs, on the assumption that the domain of objects and that of eventualities have the structure of join semi-lattices:

Aspectual composition: When the Incremental Theme is cumulative, the whole predication is cumulative (atelic); when the Incremental Theme is quantized, the predication is quantized (telic), provided the predication describes singular eventualities and all else being equal.

$\phi = \lambda e \exists x\, [\alpha(e) \wedge \delta(x) \wedge \text{Incremental\_Theme}(e, x)]$ Krifka 1992a
ϕ is quantized/cumulative if δ is quantized/cumulative

$[\![\textit{eat two apples}]\!] = \lambda e \exists x[\text{EAT}(e) \wedge \text{APPLE}(x) \wedge \#(x) = 2 \wedge \text{Incremental\_Theme}(e, x)]$
quantized quantized

$[\![\textit{eat apples}]\!] = \lambda e \exists n \exists x[\text{EAT}(e) \wedge \text{APPLE}(x) \wedge \#(x) = n \wedge \text{Incremental\_Theme}(e, x)]$
cumulative cumulative

Properties of episodic verbs for the classification of thematic roles (Krifka 1992a)

	Example	Cumulativity	Uniqueness for objects	Mapping to subevents	Mapping to subobjects	Uniqueness for events
Incremental Theme	*eat an apple*	+	+	+	+	+
Incremental Theme	*read a book*	+	+	+	—	—
Theme	*push a cart*	+	+	—	—	—

quantized P — object-event mappings

⟦*eat two apples*⟧ = λ e. ∃ x [eat(e) ∧ two-apples(x) ∧ Incremental_Theme (e,x)] QUANTIZED

⟦*eat apples*⟧ = λ e. ∃ x [eat(e) ∧ apples(x) ∧ Incremental_Theme (e,x)] CUMULATIVE

⟦*push two carts*⟧ = λ e. ∃ x [push(e) ∧ two-carts(x) ∧ Theme(e,x)] CUMULATIVE

⟦*push carts*⟧ = λ e. ∃ x [push(e) ∧ carts(x) ∧ Theme(e,x)] CUMULATIVE

cumulative P — no object-event mappings

Independence of quantization from incrementality

- Incrementality does not guarantee quantization (telicity).
  ⟦*eat apples*⟧ = λ e. ∃ x [eat(e) ∧ apples(x) ∧ Incremental_Theme (e,x)] CUMULATIVE

- Quantization (telicity) does not require incrementality.
  ⟦*sleep for 3 hours* ⟧ = λx,e[SLEEP(x, e) ∧ HOUR(τ(e)) = 3] QUANTIZED

  HOUR is a measure function over temporal traces of events (output of the temporal trace function τ (see also below)

Mereological approach to aspectual composition: consequences

- Revision of aspectual classes: Three main types of aspectual classes for episodic verbs.
  - TELIC *verbs: recover, arrive, die, notice, ...*
    inherently/lexically quantized
    QUANTIZED(P) $=_{def}$ $\forall e, e' [P(e) \wedge e' < e \rightarrow \neg P(e')]$
    Krifka 1986 and elsewhere; cf. Bach (1981): antisubdivisibility of EVENT Ps
  - ATELIC verbs: *run, rain, push (a cart), see, sleep, ...*
    inherently/lexically cumulative
    CUMULATIVE(P) $=_{def}$ $\forall e, e' [P(e) \wedge P(e') \rightarrow P(e \oplus e')] \wedge \exists e \exists e'[P(e) \wedge P(e') \wedge e \neq e']$
    Krifka 1986 and elsewhere, cf. Bach (1981): additivity of PROCESS Ps
  - INCREMENTAL verbs: *eat, drink, write, read, burn, destroy, ...*
    lexically unspecified with respect to quantization/cumulativity (Filip 1993/99)
    Terminology: "Incremental Theme", coined by Dowty (1987, 1991) for "Gradual Patient" and "Successive Patient" originally used by Krifka (1986/89, 1992a).

- The 'direct or intrinsic countability' of telic predicates (see Mourelatos 1978, p.429-30, i.a.) is not reducible to the atomicity of their denotational domain (pace Bach 1986).
  The essential property is quantization, and 'temporal quantization' as its special case.

Cross-linguistic differences in aspectual composition

The "directionality" of the "transfer of reference properties", quantization and cumulativity, predicts two main modes of aspectual composition (Krifka 1992a):

- **English, German, Finnish** (among others): "from objects to eventualities"

  The mereological properties of the Incremental Theme argument constrain the aspectual interpretation of a VP (or a whole S).

  ! Opinions differ whether the aspectual effect of the Incremental Theme argument is at the level of the telic/atelic distinction (aspectual classes, Aktionsart, aka situation aspect) or the semantics of the grammatical perfective and imperfective (possibly progressive) aspect.

- **Slavic languages, Japanese** (among others): "from eventualities to objects"

  The mereological properties of perfective and imperfective verbs (grammatical aspect) constrain the mereological properties of their bare mass and plural Incremental Theme arguments (Filip 1993/99, 1997, 2005).

  This motivates the well-known definiteness and indefiniteness effects on nominal arguments with perfective and imperfective verbs, respectively.

German: ACC / *an*-PP alternation involving the Incremental Theme argument

(1) a. Das Kind aß einen Fisch als Maija hereinkam. Krifka 2001
the child ate a fish when Maija came in
'The child ate a fish when Maija came in.'

b. Das Kind aß an einem Fisch als Maija hereinkam.
the child ate at a fish when Maija came in
'The child was eating a fish when Maija came in.'

The aspectually relevant ACC/*an*-PP alternation is tied to the Strictly Incremental Theme argument (Krifka 1989, 1992a; Filip 1989), but it may also be influenced by contextual factors (Filip 1989). Therefore, the *an*-PP member is best analyzed as a prepositional object governed by a strictly incremental verb. Roughly (following Krifka 1992a):

(2) a. *essen* ('eat'): < S/NP[nom, ag], NP[**acc**, STRICTLY_INC_THEME] >
b. *essen* ('eat'): < S/NP[nom, ag], NP[***an***-obj, **PART**-STRICTLY_INC_THEME] >
c. $\forall e, x[\textbf{PART}\text{-STRICTLY\_INC\_THEME}(e, x) \leftrightarrow \exists x'[\text{STRICTLY\_INC\_THEME}(e, x') \wedge x \leq x']]$
(2a) and (2b) are linked via a lexical redundancy rule (2c)

With a "partitive" Strictly Incremental Theme relation, the transfer of reference properties leads to the reference to parts of event predicates, with a semantic effect of
(i) progressivity (Krifka 1989, 1992a, 2001; Filip 1989, 1993/99), or
(ii) atelicity (Kratzer (2004).

Finnish: ACC / partitive case alternation

The partitive case has the effect of
(i) a progressive VP marker (Krifka 1992a, 2001)
(ii) an imperfective VP marker (Kiparsky 1998)

The accusative case has the effect of
a perfective (telic) VP marker

(1) a. Lapsi söi kalan kun Maija tuli sisään. examples and glosses from Krifka 2001
child ate fish.**ACC** when Maija came in
'The child ate a/the fish when Maija came in.'

b. Lapsi söi kalaa kun Maija tuli sisään.
child ate fish.**PART** when Maija came in
'The child was eating a/the fish when Maija came in.'

(2) a. Hän kirjoitt-i kirjee-t examples and glosses from Kiparsky 1998
He/she write-PstM3Sg letter-Pl**ACC**
'He wrote the letters' (. . . and left) telic VP, def. NP

b. Hän kirjoitt-i kirje-i-tä
He/she write-PstM3Sg letter-Pl-**Part**
(i) 'He wrote (some) letters' (. . . and left) telic VP, indef.NP
(ii) 'He was writing letters (. . . when I came) atelic VP, indef. NP
(iii) 'He was writing the letters (. . . when I came) atelic VP, def. NP

Krifka 2001: The partitive case (3b) changes a nominal predicate so that it can refer to parts of the entities in its original extension (3a).

(3) a. $[\![\textit{kalan}]\!] = \text{FISH}$
b. $[\![\textit{kalaa}]\!] = \lambda x \exists y[\text{FISH}(y) \wedge x \leq y]$

In Finnish, the alternation as in (4a) and (4b) is grammaticalized to a general way of marking
(i) the progressive/non-progressive distinction (Krifka 1992a, 2001)
(ii) the imperfective/perfective distinction (Kiparsky 1998, i.a.).

(4) a. $[\![\textit{söi kalan}]\!] = \lambda e \exists y[\text{FISH}(y) \wedge \text{EAT}(y, e)]$
b. $[\![\textit{söi kalaa}]\!] = \lambda e \exists x,y[\text{FISH}(y) \wedge x \leq y \wedge \text{EAT}(x, e)] \approx \lambda e \exists e'[[\![\textit{söi kalan}]\!](e') \wedge e \leq e']$

Slavic languages

Grammatical aspect – perfective and imperfective - influences the quantized and cumulative interpretation of bare mass and plural terms linked to the Incremental Theme role (see Wierzbicka (1967) for early observation, Polish data)

(1) On **snědl**^{PFV} kaši / olivy. Czech
he.NOM ate porridge.SG.ACC / olives.PL.ACC
'He ate (up) (all) the porridge / olives.'

(2) On **jedl**^{IMPFV} kaši / olivy.
he.NOM ate porridge.SG.ACC / olives.PL.ACC
(i) progressive: 'He was eating (the/sm) porridge / olives.' sm: unstressed *some*
(ii) general factual: 'He ate (the/sm) porridge / olives.'
(iii) habitual: 'He used to eat porridge/olives (regularly, from time to time ...)

- Slavic languages have a grammaticized perfective/imperfective distinction that marks part-whole relations in the domain of eventualities – each verb form is either perfective or imperfective.
- Slavic languages have no articles, with the exception of Bulgarian and Macedonian which have a 'post-positive' (suffixal or enclitic) definite article.
- NPs occur bare in argumental positions. The DO's in (1)-(2) are bare mass and plural terms, linked to the Incremental Theme role.

(1) On **snědl**^{PFV} kaši / olivy.
he.NOM ate porridge.SG.ACC / olives.PL.ACC
'He ate (up) (all) the porridge / olives.' quantized and definite
I.e., the whole quantity of porridge/olives that there was in the relevant situation was eaten.

(2) On **jedl**^{IMPFV} kaši / olivy.
he.NOM ate porridge.SG.ACC / olives.PL.ACC
(i) progressive: 'He was eating (the/sm) porridge / olives.' sm: unstressed *some*
(ii) general factual: 'He ate (the/sm) porridge / olives.'
(iii) habitual: 'He used to eat porridge/olives (regularly, from time to time ...)

Quantized and definite (referentially specific) interpretation: "Definiteness effect"

- In (1), but not in (2), bare mass and plural Incremental Theme arguments have a quantized and referentially specific interpretation, i.e., they refer to a *totality* of *specific* stuff, or a totality of *specific* plural individuals.

- Given that (1) and (2) only differ in the grammatical aspect of their main verbs, the definiteness effect must be due to the perfective aspect of the verb in (1).

- Grammatical aspect – perfective and imperfective – does not influence the quantized and cumulative interpretation of bare mass and plural terms, which are NOT linked to the Incremental Theme role

(3) On **ochutnal^{PFV}** kaši / olivy. Czech
he.NOM ate porridge.SG.ACC / olives.PL.ACC
'He tasted (the/some) porridge / olives.'

(4) On **chutnal^{IMPFV}** kaši / olivy.
he.NOM ate porridge.SG.ACC / olives.PL.ACC
(i) progressive: 'He was tasting (the/sm) porridge / olives.'
(ii) general factual: 'He tasted (the/sm) porridge / olives.'
(iii) habitual: 'He used to taste porridge/olives (regularly, from time to time ...)

Krifka (1986, 1992a): Mereological approach to Slavic aspectual composition

- Semantics of grammatical aspect
  - PFV aspect presupposes that the verbal P is QUANTIZED: $\lambda P \lambda e[P(e) \wedge QUANT(P)]$
  - IMPFV aspect tends to express CUMULATIVE Ps: $\lambda P \lambda e[P(e) \wedge CM(P)]$.
- Semantics of nominal arguments
  - Bare NPs (singular count, mass and plural) have either an indefinite or a definite interpretation, in dependence on context Krifka 1992a, p.50):

indefinite, cumulative	definite, quantized
$[\![\textit{kaše}]\!] = \lambda x[\text{porridge}(x)]$	$[\![\textit{kaše}]\!] = \lambda x[x = FU(\text{porridge}) \wedge \text{porridge}(x)]$
$[\![\textit{hrušky}]\!] = \lambda x[\text{pears}(x)]$	$[\![\textit{hrušky}]\!] = \lambda x[x = FU(\text{pears}) \wedge \text{pears}(x)]$
indefinite	definite, iff only 1 pear in the relevant situation
$[\![\textit{hruška}]\!] = \lambda x[\text{pear}(x,1)]$	$[\![\textit{hruška}]\!] = \lambda x[x = FU(\lambda x.\text{pear}(x,1)) \wedge \text{pear}(x,1)]$

  - Definite *NP*s are represented as predicates applying to the FUSION (FU) of all *P*-elements (all *P* quantities), which amounts to the claim that all *NP*s in the definite interpretation are quantized. Bare mass and plural NPs in their indefinite interpretation are cumulative.
- Aspectual composition
  - Perfective predicates enforce a quantized interpretation of the Incremental Theme argument, which is necessarily definite, if it is bare mass or plural.
  - Imperfective predicates enforce a cumulative, and hence indefinite, interpretation, but this is only a weak requirement (Krifka 1992a, p.50).

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Appendix

- **Theoretical background: Neo-Davidsonian event semantics**

The so-called "neo-Davidsonian" semantics goes beyond Davidson (1967) in so far as the arguments of the verb are treated as conjuncts, on a par with adjuncts in the original proposal of Davidson. The implementation goes beyond Davidson in two respects, which are mutually independent:

(i) Arguments and adjuncts are expressed by two-place predicates (AGENT, THEME, AT) denoting relations between an event argument and some participant argument (aka object)[1].
Arguments are predicates of the event argument.

$\exists y \exists x \exists e$ [HUG(e) $\wedge$ AGENT(e, x) $\wedge$ THEME(e, y) $\wedge$ AT(e, midnight)]

$\exists y \exists x \exists e$ [HUG(e) $\wedge$ AGENT(e) = x $\wedge$ THEME(e) = y $\wedge$ AT(e) = midnight]

In words: There is an event e such that e is a hugging by *x* (Agent participant) of *y* (Theme participant) at midnight.

(ii) Verbs are one-place predicates of eventualities: e.g., HUG(e) denotes a set of hugging eventualities.
Verbs are NOT relations!

[1] Participant arguments labeled with thematic roles like 'AGENT', 'THEME' (see Higginbotham 2000, and many others)

A quick comparison: FOL and Davidson(ian) representations

	John hugged Mary.	***hug***
FOL:	hug (John, Mary)	2-place predicate relation between objects
Davidson (1967): [see (17)]	(∃x)(hugged (John, Mary, x)) 'x': additional argument variable ranging over actions/events 'There exists some event e which is a hugging of John by Mary.'	3-place predicate relation between events and objects relation between a hugging event, John and Mary
Davidsonian event semantics	∃e[hug (John, Mary, e)] 'e': the event argument	
Neo-Davidsonian event semantics	∃e[hug (e) ∧ Agent (e, j) ∧ Theme (e, m)]	1-place predicate of eventualities a set of events of John hugging Mary

Comparison: representations of propositions headed by *butter*

(1) using existential quantification to bind the variables

a.	∃y∃x [BUTTER(x,y)]	FOL
b.	∃y∃x∃e [BUTTER(e,x,y)]	Davidsonian
c.	∃y∃x∃e [BUTTER(e) ∧ Subj(e,x) ∧ Obj(e, y)][1]	Neo-Davidsonian
c.'	∃y∃x∃e [BUTTER(e) ∧ AGENT(e) = x ∧ THEME(e) = y][2]	

(2) using lambda abstraction operator to bind the variables

a.	λyλx [BUTTER(x,y)]
b.	λyλxλe [BUTTER(e,x,y)]
c.	λyλxλe [BUTTER(e) ∧ AGENT(e) = x ∧ THEME(e) = y]

[1] Participant args labeled with grammatical functions 'Subj', 'Obj', etc. (Parsons 1980, 1990, Ch.4)

[2] Participant args labeled with thematic roles like 'AGENT', 'THEME' (Higginbotham 2000, and many others)

Packaging and grinding

Generally, context-dependent meaning shifts, as in English, pose a challenge for the principle of compositionality, since they involve a type-mismatch and/or a nontransparent meaning. This challenge has been addressed by a variety of mechanisms: namely, lexical ambiguity, polysemy, coercion/type-shifting, syntactic movement, zero morphology (identity operations in the syntax of words) or lexical underspecification with respect to mass/count and process/event. Which kind of mechanism is best suited to resolve the type-mismatch in question is a matter of continuing debates, which, however, still have not clarified what are in fact the substantial and qualitative differences among different proposals, and neither is there agreement with respect to what empirical evidence should serve for distinguishing among them and for evaluating their empirical predictions.

Packaging and grinding: Morphology and syntax

- The difference between context-dependent shifts with no formal marking in the form of words and shifts that must or may be formally marked opens up two basic options for the analysis of context-dependent shifts with no overt morphological support, as in English (Bach 1986, p.11):

  (i) Should we assume null formation rules (identity functions in the syntax of words) for forming the shifted counterparts to input count and non-count expressions?

  (ii) Or should we assume meaning for words that are lexically underspecified for the mass/count and process/event distinctions, formally and semantically?

Packaging and grinding: Morphology and syntax

- The vast majority of base (underived) verbs in natural languages is process or state. This means that base predicates typically come only with a *qualitative* criterion of application.

- Event verbs arguably have a *quantitative* criterion of application in their inherent lexical meaning, what counts as "one" event in their denotation (see Mourelatos 1978); the number of such basic verbs (root or stem verbs) base seems rather limited in natural languages (cf. Kratzer 2004, Filip & Rothstein 2005).

- The non-count to count sort-shift amounts to adding the quantitative criterion of application, and natural languages have a wealth of formal means for this purpose, syntactic constructions and morphological means. This formal complexity could be seen as a correlate of the lack of semantic systematicity observed by Bach (1986). Examples:

  - German verbal prefixes. (A lot of lexical idiosyncracy, not all the German prefixes attach to all base verbs, often prefixal uses have no compositional (predictable) semantics.)
  - measure and classifier constructions in the nominal domain

- Speculation: There seem to be less overt formal means for inducing the count-to-mass and event-to-process shifts, which are systematic and predictable, according to Bach (1986).

Packaging and grinding: Morphology and syntax

- In English, the meaning shifts between count and non-count require no overt marking in the form of words or by some other formal means, but are triggered by the context. There are languages in which overt means are required or optionally used to signal such shifts.

- Example: "Packaging" of verb meanings in German by means of prefixes

PROCESS:	⟶	EVENT
das Brot essen		das Brot **auf**essen
the bread eat		the bread auf-eat
'to (be) eating the bread'		'to eat the bread up'
blühen		**ver**blühen
blossom		ver-blossom
'blossom'		'wilt up'

Barry Taylor. 1977. "Tense and Continuity."

- MAIN TOPIC: temporal analysis of the English progressive and its interaction with Aristotle's classes
- THEORETICAL BACKGROUND: interval semantics (similarly as Bennett & Partee 1972)
- PROPOSAL: Temporal meaning postulates for PROCESS (*energeia*) and EVENT (*kinêsis*)
  - If α is a *kinesis* predicate, then if $\alpha(x)$ is true at *I*, then $\alpha(x)$ is false at all subintervals of *I*.
  - If α is an *energeia* predicate, then if $\alpha(x)$ *is* true at *I*, then $\alpha(x)$ *is* true for all subintervals of *I* which are larger than a moment.

Improvement on Bennett&Partee's (1972) subinterval requirement of the truth "at every subinterval of *I* including every moment of time in *I*."

Barry Taylor. 1977. "Tense and Continuity."

- NEW PROBLEM: Taylor's subinterval property is still too strong and does not apply to all process verbs: e.g., *chuckle* describes situations that have proper parts that are larger than a moment but still too small to count as chuckling. They stand to chuckling as a sultana stands to fruitcake: A given single sultana contained in a lump of fruitcake does not qualify as a minimal part of fruitcake.

- NEW PROPOSAL: In addition to (and perhaps instead of) temporal meaning postulates, we may try to understand at least some properties of the Aristotelian classes via SPACE-TIME PARALLELS, and part-whole relations in the domain entities and situations: analogy drawn between the temporal properties of process and event verbs and the spatial properties of stuffs and substances (countable entities).

Barry Taylor. 1977. "Tense and Continuity."

SPACE-TIME PARALLELS and part-whole relations

- What COUNT (SORTAL) nouns denote is *not* homogeneous: A clock is not made up of clocks. Similarly, EVENT (*kinêsis*) verbs like *stab* describe situations that have no proper parts that could count as stabbing.

- What MASS nouns denote is 'like-parted' or homogeneous: If some stuff is gold, then all its parts are gold (down to the relevant minimal parts). Similarly, PROCESS (*energeia*) verbs like *fall* describe situations that are homogeneous.

- In analogy to heterogeneous mass nouns like *fruitcake*, we also have heterogeneous PROCESS (*energeia*) verbs like *chuckle*.

EVIDENCE for SPACE-TIME PARALLELS observed by Taylor (1977)

Alexander Mourelatos. 1978. "Events, Processes and States."

1. NOMINALIZATION

- event predications correspond to nominalizations (gerunds and deverbative nouns formed with *-ion, -ment, -al, -ure*) that are count-quantified existential constructions:
  Vesuvius erupted three times. → *There were three eruptions of Vesuvius.*

- process predications correspond to nominalizations that are mass-quantified existential constructions:
  Onlookers shoved and screamed. → *There was shoving and screaming.*
  NOT: There was *a shoving and a screaming.

2. COOCCURRENCE WITH QUANTIFIERS

EVENT: The boat capsized 3 times. COUNT: 3 dogs were in the yard.
PROCESS: John slept (*)3 times last night. MASS: *3 muds were on the floor.

- Only EVENTS "can be directly or intrinsically counted" (Mourelatos 1978, p.209), they "fall under SORTS that provide a PRINCIPLE of count" (ibid.).

John ate an apple (Krifka 1986 and elsewhere)

$[\![\textit{eat}]\!] = \lambda x \lambda y \lambda e[\textbf{eat}\ (x, y, e)]$

$[\![\textit{an apple}]\!] = \lambda S \lambda x \lambda e \exists y[\textbf{apple}(y,1) \wedge S(x, y, e)]$

$[\![\textit{eat an apple}]\!] = \lambda S \lambda x \lambda e \exists y[\textbf{apple}(y,1) \wedge S(x, y, e)](\lambda x \lambda y \lambda e[\textbf{eat}\ (x, y, e)])$

$= \lambda x \lambda e \exists y[\textbf{apple}(y,1) \wedge \textbf{eat}\ (x, y, e)]$

$[\![\textit{John}]\!] = \lambda R \lambda e\ [R(\textbf{John}, e)]$

$[\![\textit{John eat an apple}]\!] = \lambda R \lambda e[R(\textbf{John}, e)]\ (\lambda x \lambda e \exists y[\textbf{apple}(y,1) \wedge \textbf{eat}\ (x, y, e)]\ )$

$= \lambda e\ [\ \lambda x\ \exists y[\textbf{apple}(y, 1) \wedge \textbf{eat}\ (x, y, e)]\ (\textbf{John}, e)]$

$= \lambda e \exists y[\textbf{apple}(y,1) \wedge \textbf{eat}\ (\textbf{John}, y, e)]$

PAST $= \lambda P \exists e[e \leq \text{now} \wedge P(e)]$

$[\![\textit{John ate an apple}]\!] = \lambda P \exists e[e \leq \text{now} \wedge P(e)]\ (\lambda e \exists y[\textbf{apple}(y,1) \wedge \textbf{eat}\ (\textbf{John}, y, e)])$

$= \exists e \exists y[e \leq \text{now} \wedge \textbf{apple}(y,1) \wedge \textbf{eat}\ (\textbf{John}, y, e)]$