

The common core of distributivity, aspect and measurement*

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1 Introduction

The primary objective of my research program is to strengthen the empirical and formal connections between domains which are traditionally addressed by separate areas of research within formal semantics.

In this talk, I will build a bridge between aspect, measurement, and distributivity. Its central pillar will be a higher-order property I will call **stratified reference**.

I will show that this concept is general enough to generalize and connect several notions familiar to semanticists, such as atelicity and distributivity, and formally precise enough to transfer insights across unrelated bodies of literature.

2 Background – Some terminology

2.1 What is aspect?

- In general: a lot of things depending on who you ask.
- In this talk: the **telic-atelic opposition**

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- Atelic predicates: walk, sleep, eat apples, run, run towards the store
(\approx *as soon as you start X-ing, you have already X-ed*)
- Telic predicates: build a house, eat ten apples, run to the store
(\approx *you need to reach a set terminal point in order to have X-ed*)

2.2 What is measurement?

- In everyday life: determining and comparing amounts
- In this talk: the constructions we use to talk about measurement
- I will mainly work with the *measure pseudopartitive* construction:
 - (1) three liters of water
- But similar points apply also to true partitives (*three liters of the water*)
comparative determiners (*more water*).

I'll get to distributivity later.

3 The measurement puzzle

Pseudopartitives and comparative determiners reject certain measure functions like *speed* and *temperature* (Krifka, 1998; Schwarzschild, 2006)

- | | | |
|-----|------------------------------------|-----------------------|
| (2) | a. five pounds of rice | <i>weight</i> |
| | b. five liters of water | <i>volume</i> |
| | c. five hours of talks | <i>duration</i> |
| | d. five miles of railroad tracks | <i>spatial extent</i> |
| | e. *five miles per hour of driving | <i>*speed</i> |
| | f. *five degrees Celsius of water | <i>*temperature</i> |
- (3) more rope *by length / by weight / *by temperature*

3.1 Questions

1. How can we characterize the class of admissible measure functions in these constructions?
 - Previous answers available but unsatisfying
2. Why are not all measure functions admissible in the first place?
 - No previous answers: We will look at aspect for an answer.

3.2 Previous attempts at characterizing the restriction

Pseudopartitives have been claimed to only accept measure functions that are *monotonic* (Schwarzschild, 2006).

- A measure function μ is *monotonic* iff for any two entities a and b in the model (\approx physical world), if a is a proper part of b , then $\mu(a) < \mu(b)$.

A similar claim is made in Krifka (1998). My remarks apply to both accounts.

Examples:

- Volume is monotonic because any proper part of an entity always has a smaller volume than that entity. \rightsquigarrow *thirty liters of water*
- Temperature is not monotonic because a proper part of an entity is not colder than that entity. \rightsquigarrow **thirty degrees Celsius of water*
- What about height? It had better be monotonic: \rightsquigarrow *five feet of snow*

Problem: If height is monotonic, any proper part of an entity has a smaller height than that entity. Last night, five feet of snow fell on Berlin. The snow that fell on West Berlin is a proper part of the snow that fell on Berlin. But, we don't conclude that the height of the snow in West Berlin was less than five feet. So height is **not monotonic**.

Schwarzschild's response: we redefine monotonicity with respect to a pragmatically supplied parthood relation and we assume that the snow in West Berlin is not a pragmatic part of the snow in Berlin.

- This proposal is difficult to evaluate: he does not give clear criteria to decide when something is a pragmatic part of something else.

Conceptual problem: Characterizing the admissible functions is a description, not an explanation.

3.3 Novel observation

Measure functions rejected by pseudopartitives are also rejected by *for*-adverbials.

- | | | | |
|-----|----|--------------------------------|-----------------------|
| (4) | a. | five hours of talks | <i>duration</i> |
| | b. | five miles of railroad tracks | <i>spatial extent</i> |
| | c. | *five miles an hour of driving | <i>*speed</i> |
| | d. | *five degrees Celsius of water | <i>*temperature</i> |

- (5) a. John waited for five hours. *duration*
 b. The crack widens for five meters. *spatial extent*
 c. *John drove for thirty miles an hour. **speed*
 d. *The soup boiled for 100 degrees Celsius. **temperature*

Examples (5c) and (5d) are surprising – after all, it’s possible to talk about speed and temperature in other ways:

- (6) a. John drove (at) thirty miles an hour. *speed*
 b. The soup boiled at 100 degrees Celsius. *temperature*

4 Answer strategy

For-adverbials are most commonly associated with the telic/atelic opposition.

- (7) a. John **talked** for five minutes. *atelic*
 b. *John **finished talking** for five minutes. *telic*
- (8) a. John **ate apples** for an hour. *atelic*
 b. *John **ate ten apples** for an hour. *telic*

There is no previous work on *for*-adverbials and measurement. But the empirical connection between pseudopartitives and *for*-adverbials allows us to tap into the literature on aspect.

To do this, I will:

- Present a formal view of the fact that *for*-adverbials reject telic predicates.
- Motivate a constraint which generalizes the telic-atelic opposition and relate it to pseudopartitives.
- Derive the restriction on measure functions from this constraint.

5 The aspect puzzle: What does it mean to be atelic?

The same event can be described by the predicates *run* (atelic) and *run to the store* (telic). So telicity is a property of predicates (Krifka, 1998), a higher-order property. But which one?

Classical answer To be atelic means to have the *subinterval property* (e.g. Bennett and Partee, 1972; Dowty, 1979). Here’s an event-based version of it:

- (9) $\text{SUBINT}(P) =_{def} \forall e[P(e) \rightarrow \forall i[i < \tau(e) \rightarrow \exists e'[P(e') \wedge e' < e \wedge i = \tau(e')]]]$
 (Whenever P holds of an event e , then at every subinterval of the runtime of e , there is a subevent of which P also holds.)

On a Dowty-style account, *for*-adverbials presuppose the subinterval property. Telic predicates are ruled out because they lack this property.

- (10) *eat ten apples for three hours
Failing presupposition: $\text{SUBINT}(\llbracket \text{eat ten apples} \rrbracket)$, i.e. every part of the runtime of an eating-ten-apples event e is the runtime of another eating-ten-apples event that is a part of e .

5.1 Problems with the subinterval property

First problem The “minimal-parts problem” (Taylor, 1977; Dowty, 1979): The subinterval property distributes P literally over all subintervals. This is too strong.

- (11) John and Mary waltzed for an hour
 $\not\Rightarrow$ #John and Mary waltzed within every single moment of the hour
 \Rightarrow John and Mary waltzed within every short subinterval of the hour

The length interval that counts as very small for the purpose of the *for*-adverbial varies relative to the length of the bigger interval:

- (12) The Chinese people have created abundant folk arts ... passed on from generation to generation for thousands of years.¹

Second problem The subinterval property contains a hard-coded reference to time. But this is not sufficiently general: Spatial *for*-adverbials test for spatial atelicity but work analogously to temporal ones otherwise. (Gawron, 2005)

- (13) a. The crack **widens** for 5 meters. *spatially atelic*
 b. *The crack **widens 2cm** for 5 meters. *spatially telic (but stative!)*

Spatial and temporal *for*-adverbials do not have the same distribution, so they impose different constraints – see Figure 1.

- (14) a. John pushed carts to the store for fifty minutes. *temporally atelic*
 b. #John pushed carts to the store for fifty meters. *spatially telic*

¹Attested example (<http://www.twinbridge.com/detail.aspx?ID=315>). Nov 15, 2010.

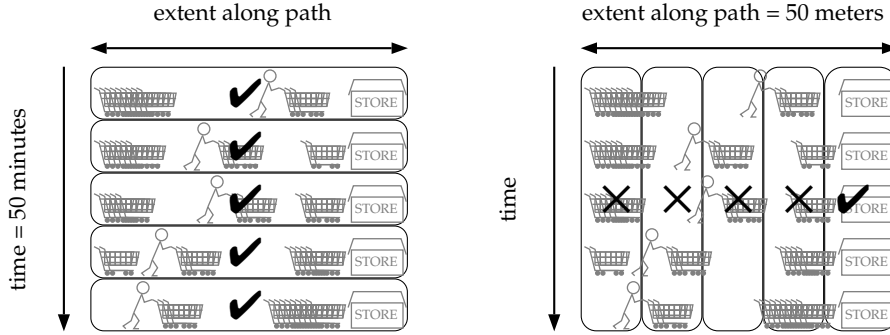


Figure 1: *John pushed carts to the store* is temporally atelic but spatially telic

5.2 Generalizing the subinterval property

What the subinterval property says: An atelic predicate P distributes along the *time* dimension down to intervals of *infinitely short length*.

What it should say: An atelic predicate P distributes along the ___ dimension down to intervals of ___ length.

That is, we want to *parametrize* the subinterval property.

We start with applying the subinterval property to *waltz*:

- (15) $\forall e[\text{waltz}(e) \rightarrow \forall i[i < \tau(e) \rightarrow \exists e'[\text{waltz}(e') \wedge e' < e \wedge i = \tau(e')]]]$
 (Whenever *waltz* holds of an event e , then at every subinterval of the runtime of e , there is a subevent of which *waltz* also holds.)

We want to distribute over “very small” events. I assume that ε is a function that tells us what counts as very small. For example, $\varepsilon(\lambda t[\text{hours}(t) = 1])(t')$ is true just in case t' is very small with respect to one hour.

We want to be able to say:

- (16) Whenever *waltz* holds of an event, there is a way of dividing this event into subevents with very small runtimes such that *waltz* also holds of each of these subevents.

To express this formally, we use the star operator from Link (1987)’s work on plurality and distributivity.

- $x \in *(\lambda y.\varepsilon(y) \wedge B(y))$ means: x consists of one or more ε -sized parts of which B holds

Technical background: $A \in *P$ is defined as $\exists C[A = \bigoplus C \wedge C \subseteq P]$
 (A is the sum of all the elements of a subset C of P)

With the star operator, we can express (16) as follows:

$$(17) \quad \forall e[\text{waltz}(e) \rightarrow e \in {}^*\lambda e' \left(\begin{array}{l} \text{waltz}(e') \wedge \\ \varepsilon(\lambda t[\text{hours}(t) = 1])(\tau(e')) \end{array} \right)]$$

Let us say that *waltz* has **stratified reference** (SR) with respect to the dimension τ (“runtime”) and the granularity $\varepsilon(\lambda t[\text{hours}(t) = 1])$ (“very short time interval”) just in case (17) above is true.

$$(18) \quad \text{Stratified reference (Example)} \\ \text{SR}_{\tau, \varepsilon(\lambda t[\text{hours}(t) = 1])}(\lambda e[\text{waltz}(e)]) \Leftrightarrow (17)$$

By abstracting from this example, we arrive at the following definition (the predicates and variables are meant to be untyped, e.g. x ranges over both individuals/substances and events):

$$(19) \quad \text{Stratified reference (Definition)} \\ \text{SR}_{f, \varepsilon(K)}(P) \stackrel{\text{def}}{=} \forall x[P(x) \rightarrow x \in {}^*\lambda y \left(\begin{array}{l} P(y) \wedge \\ \varepsilon(K)(f(y)) \end{array} \right)]$$

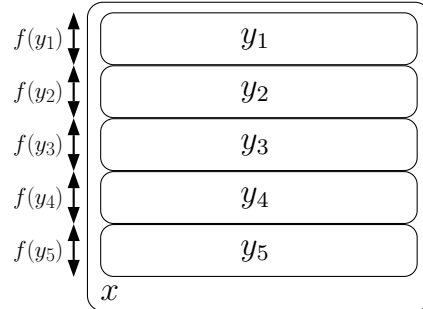


Figure 2: Illustration of stratified reference

The answer to the aspect puzzle.

We can now say: Being atelic means having stratified reference with respect to time and a suitably instantiated granularity parameter.

For-adverbials presuppose stratified reference, not the subinterval property:

$$(20) \quad \text{waltz for an hour} \\ \text{Satisfied presupposition:} \\ \forall e[\text{waltz}(e) \rightarrow e \in {}^*\lambda e' \left(\begin{array}{l} \text{waltz}(e') \wedge \\ \varepsilon(\lambda t[\text{hours}(t) = 1])(\tau(e')) \end{array} \right)]$$

(Every waltzing event consists of waltzing subevents whose runtimes are very small compared to an hour.)

(21) push carts for three hours

Satisfied presupposition:

$$\forall e[\llbracket\text{push carts}\rrbracket(e) \rightarrow e \in {}^*\lambda e' \left(\begin{array}{l} \llbracket\text{push carts}\rrbracket(e') \wedge \\ \varepsilon(\lambda t[\text{hours}(t) = 3])(\tau(e')) \end{array} \right)]$$

(Every event in which one or more carts are pushed consists of subevents in which one or more carts are pushed and whose runtimes are very small compared to three hours.)

Note: I assume following Zweig (2008) and others that $\llbracket\text{push carts}\rrbracket =$ “push one or more carts”, not “push two or more carts” (the “two or more” is an implicature)

(22) *eat ten apples for three hours

Failing presupposition:

$$\forall e[\llbracket\text{eat ten apples}\rrbracket(e) \rightarrow e \in {}^*\lambda e' \left(\begin{array}{l} \llbracket\text{eat ten apples}\rrbracket(e') \wedge \\ \varepsilon(\lambda t[\text{hours}(t) = 3])(\tau(e')) \end{array} \right)]$$

(Every eating-ten-apples event consists of eating-ten-apples subevents whose runtimes are very small compared to three hours.)

6 Back to the measurement puzzle

Why can you not say **thirty degrees of water?*

We have seen that *for*-adverbials are incompatible with measure functions like *speed* and *temperature*:

- (23) a. *John drove for thirty miles an hour. **speed*
 b. *The soup boiled for 100 degrees Celsius. **temperature*

Null assumption These sentences have the same presuppositions as sentences with temporal and spatial *for*-adverbials, except that time/space has been replaced by speed/temperature. This assumption predicts presupposition failures for (23):

(24) *drive for thirty miles per hour

Failing presupposition: $\text{SR}_{\text{speed},\varepsilon}(\llbracket\text{thirty mph}\rrbracket)(\llbracket\text{drive}\rrbracket)$

(Every driving event consists of driving subevents whose speeds are very small compared to thirty mph.)

(25) *boil for 100 degrees Celsius

Failing presupposition: $\text{SR}_{\text{temperature},\varepsilon}(\llbracket\text{100 degrees}\rrbracket)(\llbracket\text{boil}\rrbracket)$

(Every boiling event consists of boiling subevents whose temperatures are very small compared to 100 degrees.)

To transfer this idea to pseudopartitives, we make use of a parallel between distinctions in the nominal and in the verbal domain (e.g. Bach, 1986; Krifka, 1998):

atelic : telic
 \therefore
mass/plural : singular count

Both telic predicates and singular count nouns are *quantized* (Krifka, 1998): they do not apply to the parts of the entities or events in their denotation.

$$(26) \quad \text{QUA}(P) \stackrel{\text{def}}{=} \forall x [P(x) \rightarrow \neg \exists y [y < x \wedge P(y)]]$$

Pseudopartitives reject singular count nouns:

- | | | |
|------|--|--|
| (27) | a. five pounds of books
b. thirty liters of water
c. *five pounds of book | <i>plural</i>
<i>mass</i>
<i>*singular</i> |
|------|--|--|

Intuition: *run for three hours* \approx *three hours of running*

6.1 Crossing the bridge again

Assumption: The same presupposition that is found in *for*-adverbials is also found in pseudopartitives, just with other parameters.

6.2 Baseline examples

Event-denoting pseudopartitives work just like *for*-adverbials:

- (28) run for three hours / three hours of running
Satisfied presupposition: $\text{SR}_{\tau, \varepsilon}(\llbracket \text{three hours} \rrbracket)(\llbracket \text{run} \rrbracket)$
 (Every running event consists of running subevents whose runtimes are very small compared to three hours.)

In substance-denoting pseudopartitives, we assume that the dimension parameter is the appropriate measure function. Mass nouns like *water* are acceptable because they have divisive reference (Krifka, 1998): whenever they apply to an entity, they also apply to all of its parts.

- (29) thirty liters of water
Satisfied presupposition: $\text{SR}_{\text{volume}, \varepsilon}(\llbracket \text{thirty liters} \rrbracket)(\llbracket \text{water} \rrbracket)$
 (Every water amount consists of water parts whose volumes are very small compared to thirty liters.)

6.3 Ruling out singular count nouns

Singular count nouns are ruled out because they are quantized.

- (30) *five pounds of book
Failing presupposition: $SR_{\text{weight},\varepsilon}(\llbracket\text{five pounds}\rrbracket)(\llbracket\text{book}\rrbracket)$
(Every book consists of parts which are themselves books (!) and whose weights are very small compared to five pounds.)

6.4 Temperature in pseudopartitives

A nonmonotonic measure function like *temperature* is ruled out because smaller values are not guaranteed as you go from bigger to smaller amounts of substance.

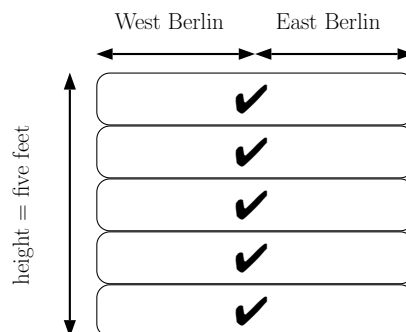
- (31) *thirty degrees Celsius of water
Failing presupposition: $SR_{\text{temperature},\varepsilon}(\llbracket\text{thirty degrees Celsius}\rrbracket)(\llbracket\text{water}\rrbracket)$
(Every water amount consists of water parts whose temperatures are very small compared to thirty degrees Celsius.)

6.5 The problematic snow example

Unlike Schwarzschild's, this account does not require the measure function in the pseudopartitive to be monotonic.

- (32) five feet of snow
Satisfied presupposition: $SR_{\text{volume},\varepsilon}(\llbracket\text{five feet}\rrbracket)(\llbracket\text{snow}\rrbracket)$
(Every snow amount consists of snow parts whose heights are very small compared to five feet.)

Figure 3: Accepting *five feet of snow*



The answers to the measurement puzzle.

1. How can we characterize the class of admissible measure functions in these constructions?
 - A measure function μ in a pseudopartitive of the form *Num N1 of N2* has to be such that $\text{SR}_{\mu, \varepsilon}(\llbracket \text{Num N1} \rrbracket)(\llbracket \text{N2} \rrbracket)$ is true.
2. Why are not all measure functions admissible in the first place?
 - The constraint on measure functions is independently attested in *for*-adverbials, and it also rejects telic predicates in *for*-adverbials and singular count nouns in pseudopartitives.

7 Distributivity

Stratified reference can also be used to gain new insights into the *distributivity-collectivity* opposition. Let me sketch one relevant application.

What is distributivity? In this talk: a property of predicates

- *Distributive*: e.g. walk, smile, take a breath (applies to a plurality just in case it applies to each of its members)
- *Collective*: e.g. be numerous, be a motley crew, suffice to defeat the army (may apply to a plurality even if it does not apply to each of its members)

7.1 Zweig's puzzle

Zweig (2008) notes that the distributive quantifier *all* normally cannot give rise to scopeless (cumulative) readings, in contrast to nondistributive quantifiers like *three*:

- (33)
- a. Three safari participants saw thirty zebras.
Available scopeless reading: Three safari participants saw at least one zebra each, and thirty zebras were seen overall.
 - b. All the safari participants saw thirty zebras.
Unavailable scopeless reading: Each safari participant saw at least one zebra, and thirty zebras were seen overall.

Dependent-plural readings, which Zweig shows are scopeless, are an exception. Here *all* patterns with *three*:

- (34) a. Three safari participants saw zebras.
Available scopeless reading: Three safari participants saw at least one zebra each, and at least two zebras were seen overall.
- b. All the safari participants saw zebras.
Available scopeless reading: Each safari participant saw at least one zebra, and at least two zebras were seen overall.

Sketch of an explanation. Assume that *all* imposes **stratified reference down to atomic agents**. In other words, *all* presupposes that the agent of every VPing event consists of one or more atomic parts that are agents of VPing events.

- (35) **Presupposition of *all*:** $\forall e[\text{VP}(e) \rightarrow e \in * \lambda e' \left(\begin{array}{l} \text{VP}(e') \wedge \\ \text{Atom}(\text{ag}(e')) \end{array} \right)]$

Evidence comes from certain collective predicates (Kroch, 1974; Dowty, 1987):

- (36) a. The men who run this country are politically homogeneous.
 b. The people on this boat are a motley crew.
 c. The soldiers in this bataillon sufficed to defeat the army.
- (37) a. *All the men who run this country are politically homogeneous.
 b. *All the people on this boat are a motley crew.
 c. *All the soldiers in this bataillon sufficed to defeat the army.

Now we can rule out the scopeless reading of (33b) as a presupposition failure:

- (38) **Failing presupposition:** $\text{SR}_{\text{agent}, \text{Atom}}(\llbracket \text{see thirty zebras} \rrbracket)$
 (Every see-thirty-zebras event consists of subevents with atomic agents and in each of which thirty zebras are seen.)

The scopeless reading of (34b) is available because the following presupposition is satisfied:

- (39) **Satisfied presupposition:** $\text{SR}_{\text{agent}, \text{Atom}}(\llbracket \text{see zebras} \rrbracket)$
 (Every event in which at least one zebra is seen consists of subevents with atomic agents and in each of which at least one zebra is seen.)

8 Summary and outlook

We have used a parametrized higher-order property, stratified reference, to

- improve on a notion developed for aspect (the subinterval property)
- solve a problem in the study of measurement
- and to get a new perspective on distributivity and scope.

Emerging bigger picture Distributivity as a higher-order property with two parameters:

- dimension: runtime, spatial extent, measure functions, thematic roles . . .
- granularity: atomic (*all*), nonatomic contextual (*for*, pseudopartitives)

8.1 Connections to other (sub)fields

Philosophy of language I've focused on applications in this talk, but much of my work touches on the ontological foundations of semantics:

- What is the nature of plural entities? What is the difference between sums and groups?
- What does it mean to form the sum of two events?
- Do verbs apply to individuals or to events?

etc.

Pragmatics What determines the relevant granularity levels over which a predicate is distributed? (Schwarzschild, 1996)

- (40)
- a. 12 kilos of 1-kilo weights
 - b. 12 kilos of 2-kilo weights
 - c. 12 kilos of 3-kilo weights
 - d. 12 kilos of 4-kilo weights
 - e. ?12 kilos of 6-kilo weights
 - f. *12 kilos of 12-kilo weights
- (Zweig, p.c.)

Syntax Does the common semantics suggest a common syntax between *for*-adverbials and pseudopartitives? See LFs in Appendix.

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Appendix

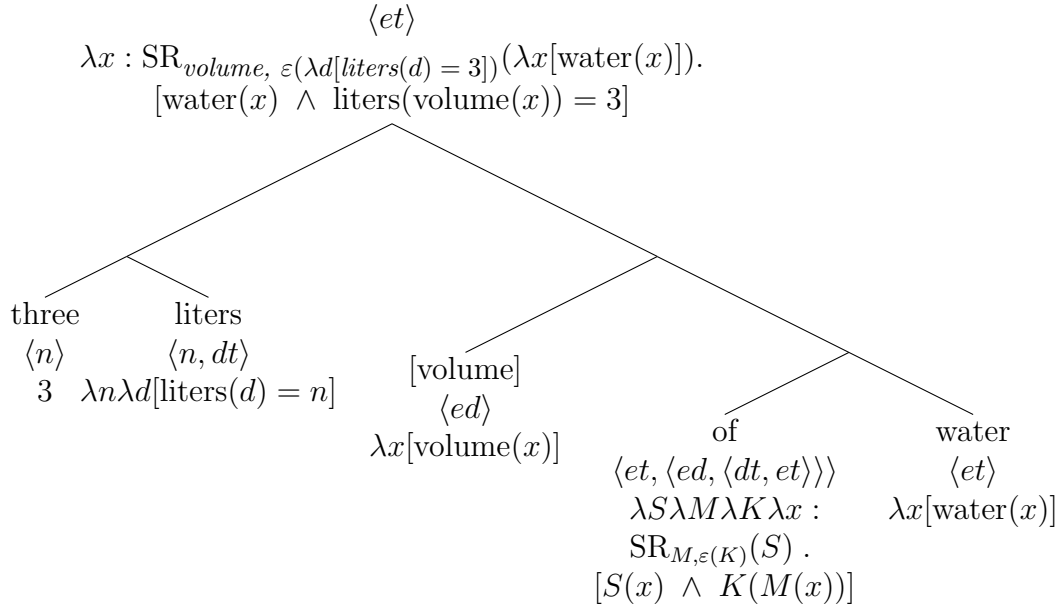


Figure 4: LF of the pseudopartitive *three liters of water*

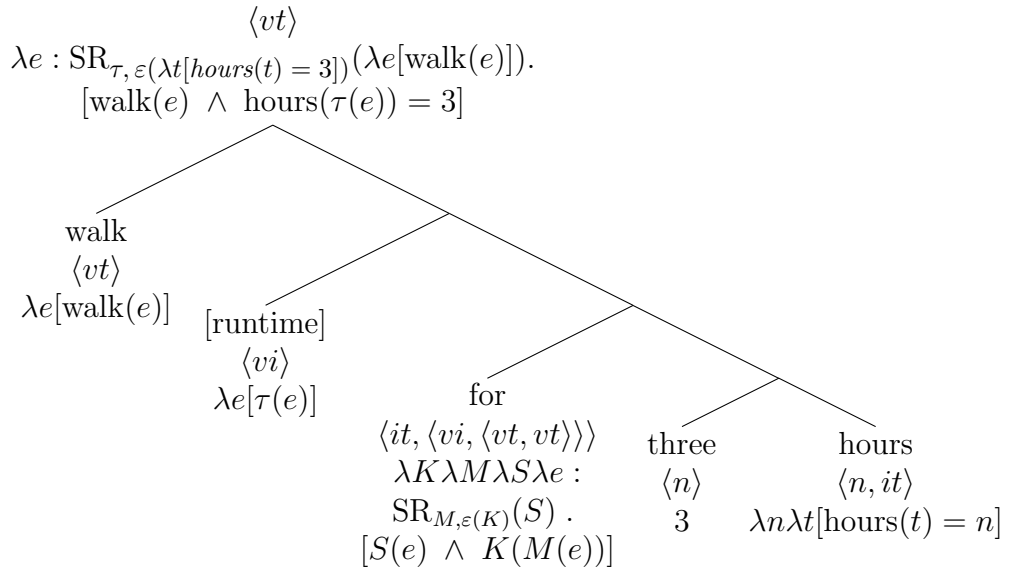


Figure 5: LF of the *for*-adverbial *walk for three hours*