Measuring out the relation between truth-conditional and conceptual semantics

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1 Overview

- We perceive the gap between truth-conditional and conceptual structures which this session addresses as pertaining to the different principles according to which the formal semantics of sentences and the conceptual semantics of lexical items is derived.
- We propose that word meaning, and in particular the meaning of morphologically complex words, is structured according to the same syntactic principles underlying the structure of sentence meaning.
- This allows us to isolate the formal components of word meaning from the conceptual components.
- We illustrate our approach to syntactically structured word semantics with spatial German denominal prefix- and particle-verbs (p-verbs).
- We argue that the contribution of conceptual semantics in word meaning shows up in the form of selection restrictions on possible fillers of argument slots of the verb.
- We propose a statistical approach to selectional preference strength as a measure on the relation between formal and conceptual semantics in a given word.

2 Pervasive semantics

2.1 Pervasive syntax

- In pervasive syntax approaches such as Distributed Morphology (overview: Harley and Noyer [1999]) or Nanosyntax (overview: Starke [2009]),
  - The same syntactic principles are assumed to be at work below and above the ’word level’;
  - Words are formed from ’roots’; atomic, non-decomposable and category-neutral elements associated with encyclopedic knowledge and which combine with features to build larger linguistic elements;
  - The term ’lexical item’ has no significance in the theory and nothing can be said to ’happen in the lexicon’
  - Our goal: provide hierarchical syntactic structure all the way down with a semantic interpretation.
  - The semantics of (morphologically complex) words is not reconstructed in the lexicon but in the syntax.
  - Note that we take the idea of structure all the way down (resp. the idea that the atomic elements of syntax and semantics are not words) as an inspiration but do not want to commit to any particular claims about morphological theory that go along with Distributed Morphology or Nanosyntax.
- Starting point of our reconstruction is the insertion of a root into a syntactic context which determines the category of the root. The semantics of the root in that particular insertion context is incrementally specified by the semantic interpretation of the syntactic structure of the insertion context.
- If the meaning of a root is determined by its insertion into a context, then the omnipresent ambiguity of spatial prepositional elements such as e.g. *über* (over/above) and nominal roots such as e.g. *lager* (store) can be identified with the insertion into different contexts (Roßdeutscher [2013a]) and thus be reconstructed in a principal manner.

2.2 Decomposition in the lexicon

- The assumption that the representation of word meaning in the lexicon is structured (and not purely denotational) has proved a fruitful starting point for the decomposition of meaning in the lexicon to conceptual structures such as
  - ’semantic forms’ (Bierwisch [2007],Wunderlich [2012])
  - ’event structure templates’ (Rappaport Hovav and Levin [1998])
  - ’dot-types’ (Asher [2011], Pustejovsky [2001]),
  - ’frames’ or ’scenarios’ (Fillmore [1982],Hamm et al. [2006])
- What all these approaches share is the assumption that word meaning is determined in the lexicon according to principles different from the principles which apply to the determination of sentence meaning in the syntax.
- Denominal p-verbs have been in the focus of interest for lexical decomposition approaches, where a noun is incorporated with a lexical process into an abstract verbal template (Kaufmann [1995], Stiebels [1998])
- Our approach is based on the insights on conceptual structures made in lexical decomposition approaches, but we reconstruct denominal verbs not in the lexicon but in the syntax.

- A thorough comparison of the lexical decomposition approach and the approach pursued in this paper is given in Roßdeutscher [2011, 2013b]).
- Further case studies on p-verbs in pervasive semantics are presented in (Roßdeutscher [2013a, 2012]), further case studies on nominalizations in (Roßdeutscher [2010], Roßdeutscher and Kamp [2010], Pross [2013]), some general information is given in (Roßdeutscher [to appear]).

2.3 Ingredients of pervasive semantics

- Minimalist syntax of phrase structure + move and merge (e.g. Adger [2003]), incorporation is governed by the head movement constraint (Travis [1984]).
- Minimalist approach to argument structure (creation of argument slots in the syntax, Hale and Keyser [1993]) and parallelism across N/V/P domains (Alexiadou [2001], Harley [2011], Svenonius [2003])
- Conceptual relations such as CAUSE, APPLICATION, SUPPORT, IN are introduced by functional layers of the structure as predications between XPs (e.g. *v*P + state-denoting XP: CAUSE) and represented in upper case
- Spatial relations between objects of vector space semantics (Zwarts [1997, 2005], Zwarts and Winter [2000]) such as $\subseteq$ (spatial inclusion), $\uparrow$ (above region) are introduced in the structure in their own functional layer.
- We use an extension of the basic DRT language (Kamp et al. [2011]) with presuppositions and a λ-calculus for variable stores where λ-conversion selects the leftmost variable from the store
- Each functional head in the syntax is responsible for the introduction and predication of a particular sort of discourse referents ("ontological building blocks")
  - v introduces events: e
  - P introduces states: s
  - n introduces invididuals: x
  - $Place$ introduces regions (sets of bounded directed vectors): r
  - $K(ase)$ introduces Eigenspace-vectors: r_{id}

3 Examples

3.1 überdachen (to over.prfx.roof.v, to cover sth. with a roof)

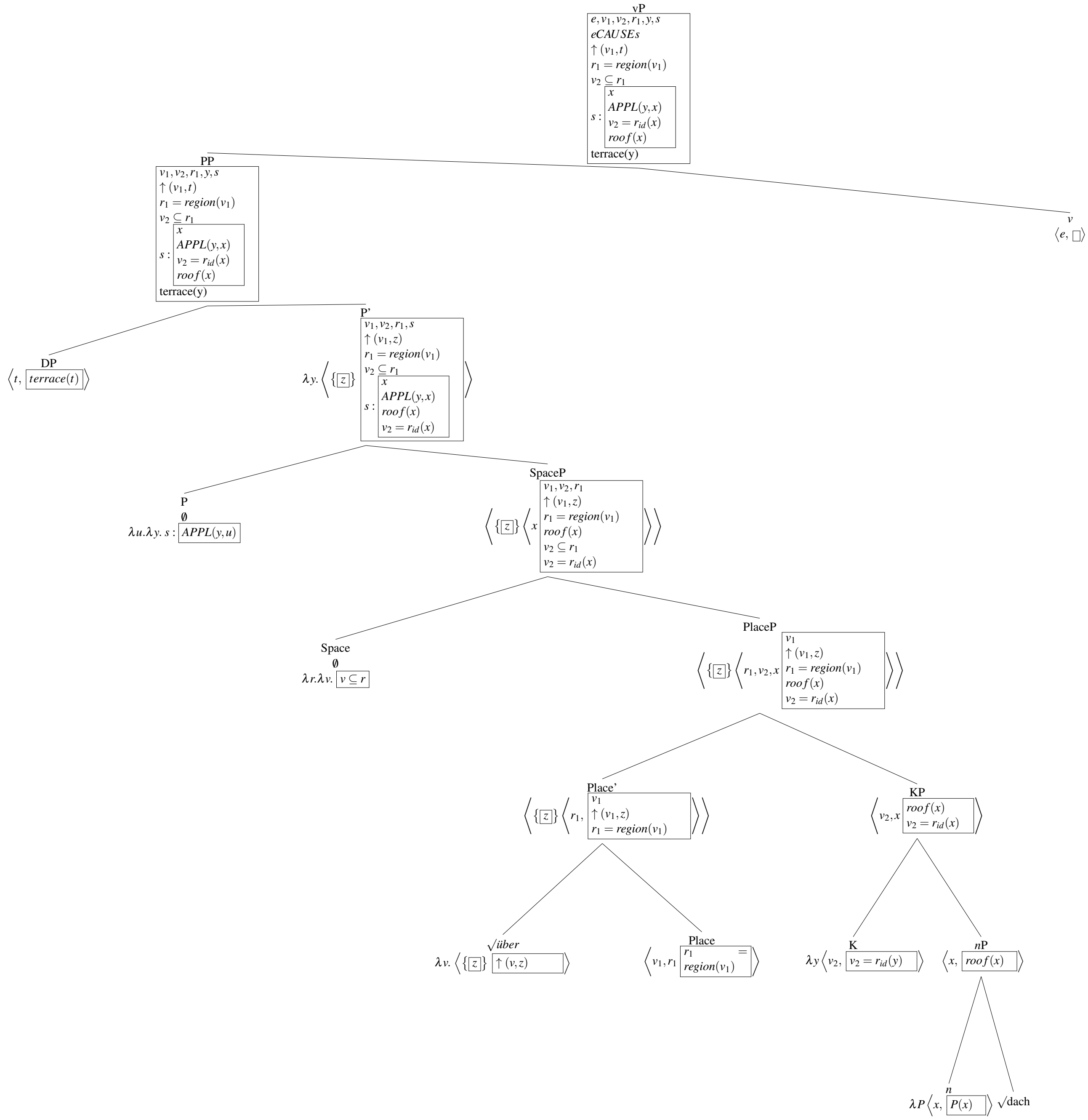
In the reconstruction (1), we distinguish two aspects of the compositional semantic structure of spatial expressions:

(a) An abstract geometrical model of space which derives truth-conditions of spatial expressions with respect to a formal theory of observer-centered vector space (in the spirit of Zwarts [1997], Kamp and Roßdeutscher [2005]). We assume that vector space semantics is determined in its own syntactic functional structure. The geometrical truth-conditions expressed by *überdachen* are derived in the structure below SpaceP.

(b) On top of SpaceP, P is responsible for conceptualizing the vector space semantics calculated at SpaceP.
  - In the present example, P conceptualizes the containment of the Eigenspace of $\sqrt{}$dach in the above region of the reference object as the application of a roof to the reference object.
  - Conceptualization of the abstract truth-conditions at SpaceP as an instance of application requires that roofs and terraces are not just geometrical objects. In order to enter the conceptual application relation in a coherent way, the geometrical objects representing terrace and roof must be conceptualized *as* a terrace or roof.
  - Conceptually, a roof is "a protective covering that covers or forms *the top of a* building" (Wordnet) and a terrace is a "usually paved outdoor *area* adjoining a residence" (Wordnet). Such conceptual knowledge is stored in the encyclopedic entry of the roots $\sqrt{}$terrasse, $\sqrt{}$dach
  - Conceptual knowledge is invoked by the conceptualization with P and is employed for evaluation of conceptual relations for conceptual coherence.
  - Conceptual coherence is captured in terms of restrictions imposed on the selection of appropriate fillers of the conceptual relation.
  - Not any objects will afford the selection restrictions involved in *überdachen* imposed by the application relation.

(1) *eine Terrasse überdachen*
a terrace over.prfx.roof

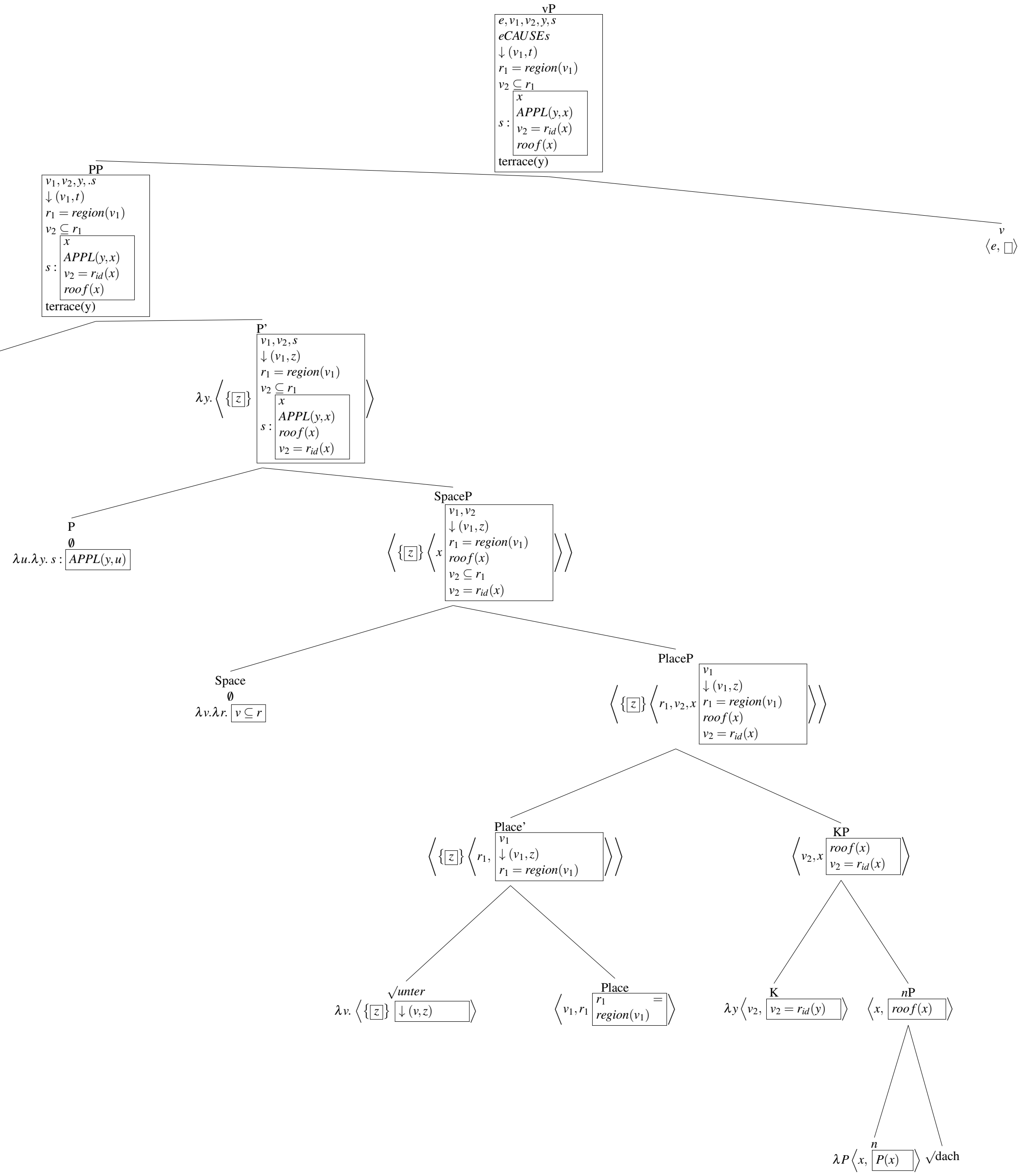
to provide a terrace with a roof



3.2 *unterdachen (to under.prx.roof.v)

- *unterdachen* (2) has the same syntactic reconstruction as (1) and has a truth-conditional interpretation according to which the geometrical object *roof* is located in the below region of the terrace.
- If a roof is conceptualized as being an object in the above region of the object which it protects, then the combination of √dach with √über is conceptually coherent. But in *unterdachen* in (2), the conceptualization runs into a problem: a roof cannot be conceptualized as being in the below region of the object with respect to which it is conceptualized as a roof. That is, although *unterdachen* describes a possible geometrical configuration, conceptualization rules out *unterdachen* as a possible word. We call this type of selection restrictions *verb-internal* selection restrictions which apply to the derivation of a word from its roots.
- More denominal application p-verbs: ummauern (to around.prfx.wall.v, to provide sth. with a wall), überpflastern (to over.prfx.cobble.v, to pave), umzäunen (to around.prfx.fence.v, to provide sth. with a fence), aufstocken (to up.prfx.story.v, to ramp up), überdeckeln (to over.prfx.lid.v, to provide sth. with a lid), überdecken (to over.prfx.cover.v, to cover), untertunneln (to under.prfx.tunnel.v, to tunnel), überbrücken (to over.prfx.bridge.v, to bridge)

(2) * *eine Terasse unterdachen*
a terrace under.prfx.roof



- The conceptualization of $\sqrt{}$über and $\sqrt{}$dach with respect to the direct object $\sqrt{}$*terrace* under the relation *APPL* requires that the direct object can be conceptualized as a bounded area which has an above region in order for the roof to be applied: a terrace fulfills these restrictions whereas a basement does not: (3b) *einen Keller überdachen* describes a possible geometrical configuration but when it is conceptualized with *APPL*, verb-external selection restrictions rule out the phrase.
- What is important to note here is that the selection restrictions imposed by conceptualization of spatial truth-conditions with the relation *APPL* can be *linguistically* observed in terms of the acceptability of direct objects and instrumental phrases.

(3) a. *eine Terrasse überdachen*
a terrace over.prfx.roof.v

b. * *einen Keller überdachen*
a basement over.prfx.roof.v

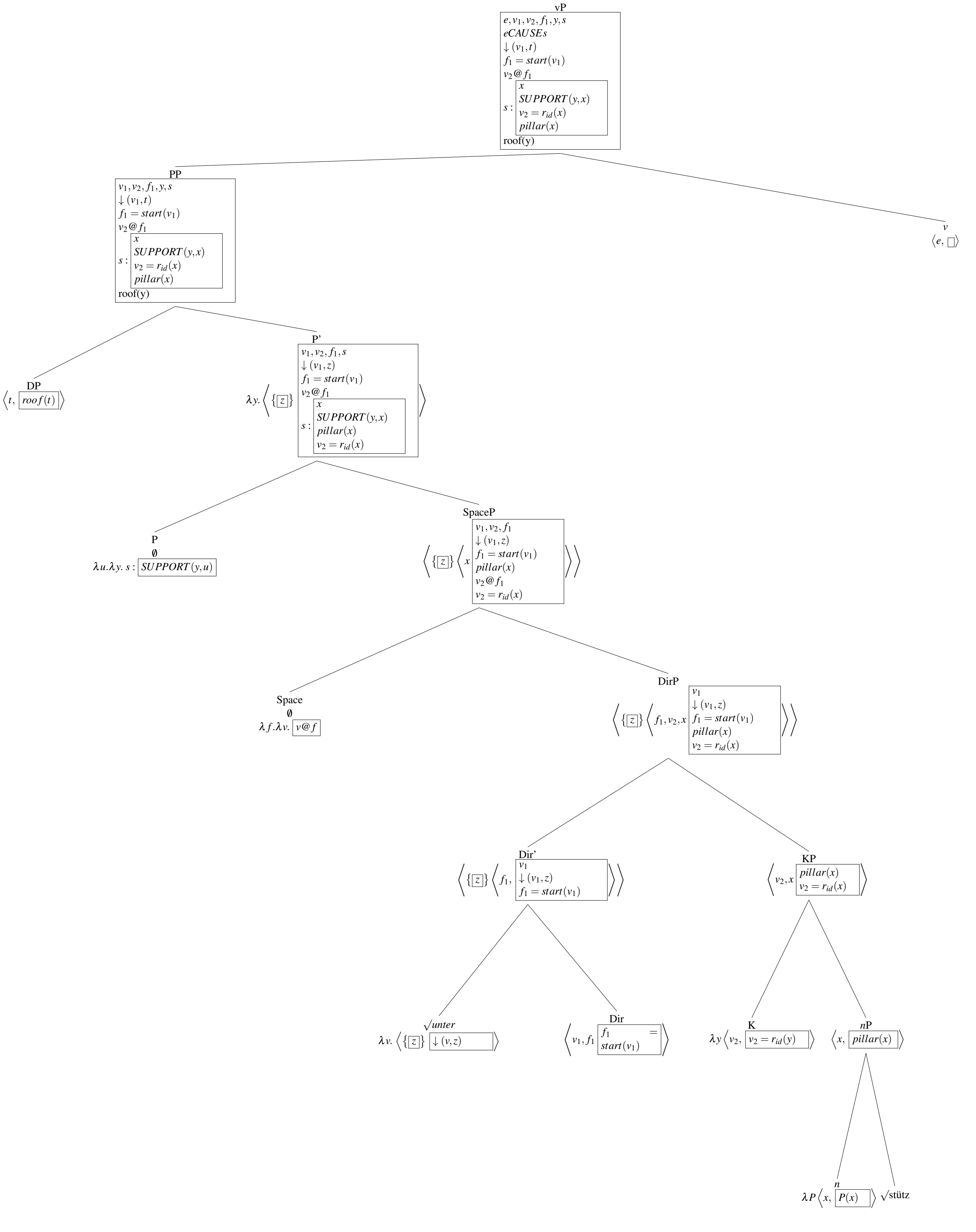
c. *eine Terrasse mit Glas überdachen*
a terrace with glass over.prfx.roof.v

d. * *eine Terrasse mit Wasser überdachen*
a terrace with water over.prfx.roof.v

3.3 unterstützen (to under.prfx.pillar.v), to support

(4) *ein Dach unterstützen*
a roof under.prfx.pillar.v

to support a roof



- The geometrical relation involved in (4) is a relation of contact of an object x with a region r (where faces are a subtype of regions): $x@r \rightsquigarrow (r_{id}(x) \bigcap r \neq \emptyset))$
- The truth-conditions of geometrical contact between objects are not enough to characterize support: there are a lot of geometrical contact configurations which cannot be conceptualized as support (e.g. a bubblegum adhering at the bottom of a table).

- In (4), the conceptualization of SpaceP with the relation *SUPPORT* between the nominal root $\sqrt{}$stütz (store, stock, mounting) and the direct object *Dach* is characterized as follows. The nominal root $\sqrt{}$stütz supports the direct object *roof* in holding up against the law of gravitation. (Note that the literal use of *unterstützen* involves gravity and that metaphorical uses may shift the domain (e.g. to the social domain, to support *someone*))
- Because *SUPPORT* conceptualizes a geometry of contact with respect to the concept of gravity, possible fillers of argument slots and instrumental phrases are restricted with respect to the way in which they relate to upholding against gravity.
- *Einen Fluss unterstützen* in (5a) is out because a river does not provide a below region into which it is attracted by the law of gravitation.

(5) a. * *einen Fluss unterstützen*
a river under.prfx.pillar.v

b. * *überstützen*
over.prfx.pillar.v

c. *ein Dach mit einem Gerüst unterstützen*
a roof with a scaffolding under.prfx.pillar.v

d. * *ein Dach mit einem Kaugummi unterstützen*
a roof with a bubblegum under.prfx.pillar.v

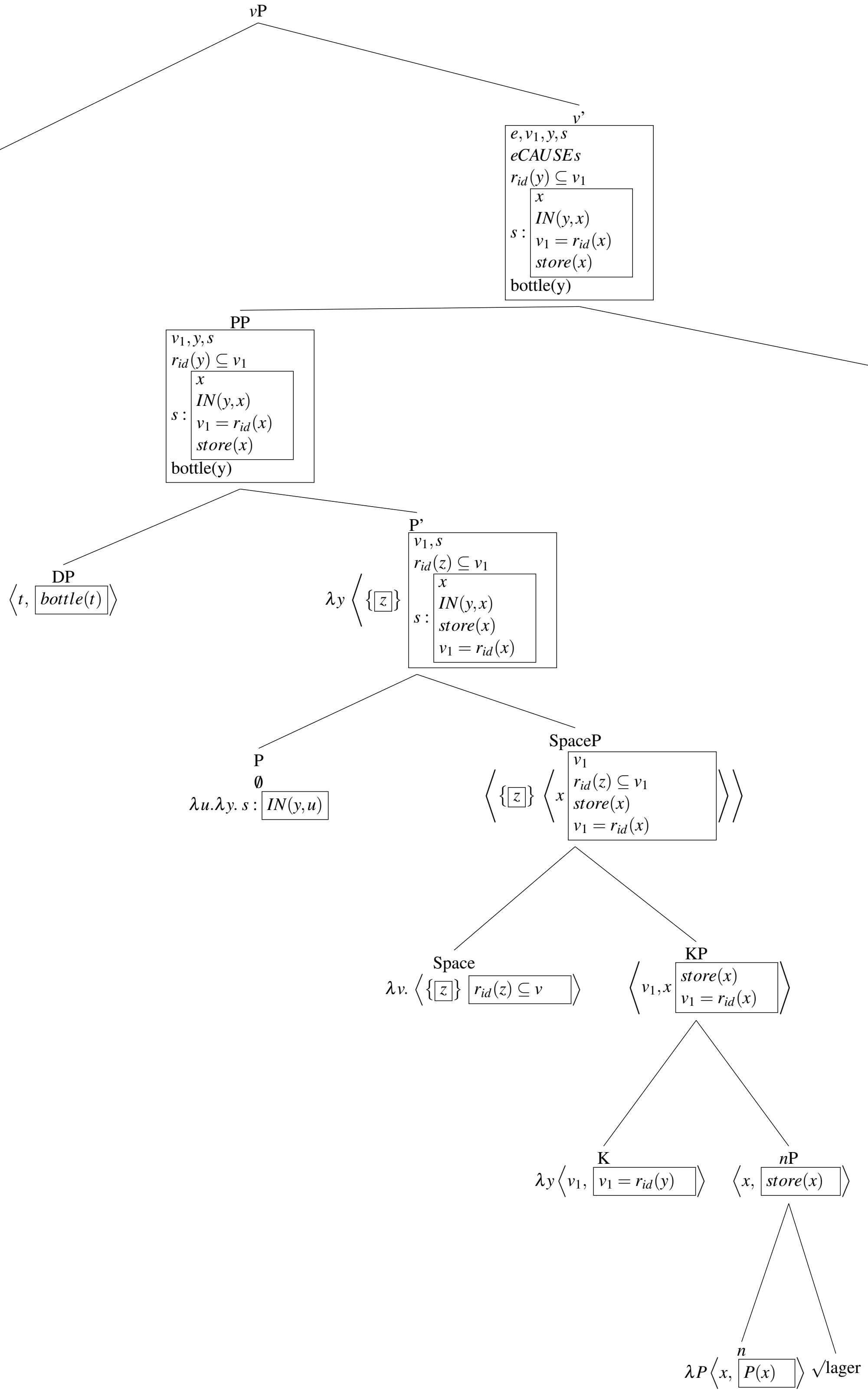
- More denominal support p-verbs: abstützen (to under.prtc.pillar.v, to underpin), aufbocken (to up.prtc.jack.v, to jack up), verstreben (to connect.prfx.strut.v, to strut), untermauern (to under.prfx.wall.v, to support with a wall), unterfüttern (to under.prfx.lining.v, to reline), aufkanten (to up.prfx.edge sth., to lay on edge), aufbahren (to up.prtc.lay.v, to lay sb. out).

3.4 einlagern (to in.prtc.store.v)

- In (6) the conceptualization of the geometry with *IN* does not impose restrictions which are not already structurally conveyed at SpaceP, namely that the geometry of the bottle is included in the geometry of the store: $IN(y,x) = r_{id}(y) \subseteq r_{id}(x)$.
- Note that the SPACE+P insertion context in (6) for $\sqrt{}$lager is only one from a set of possible insertion contexts there are other insertion contexts in which $\sqrt{}$lager is specified differently, e.g. in *etw. auf etw. auflagern* (to on.prfx.store.v sth. on sth.).
- More denominal spatial inclusion p-verbs: einsacken (to in.prtc.bag.v, to bag sth.), einsperren (to in.prtc.lock.v, to cage), einkellern (to in.prtc.cellar.v, to store in a cellar), einkerkern (to in.prtc.prison.v, to incarcerate).
- Note that the reconstruction in (6) is simplified with respect to the analysis of the particle *ein* (word-syntax is also simplified).

(6) *eine Flasche einlagern*
a bottle in.prtc.store.v

to store a bottle



4 Measuring out the relation between truth-conditional and conceptual semantics

Having illustrated our approach to pervasive semantics in the last section, we want to explore the consequences of pervasive semantics for the relation between formal and conceptual semantics in more detail now.

Selection restrictions

- Any well-formed logical form has an interpretation but not any interpretation of a well-formed logical form is conceptually coherent.
- Logical forms (whatever their extension is, individuals or geometrical objects) employed in truth-conditional semantics are insensitive to conceptual coherence.
- What distinguishes formal and conceptual semantics in our approach is not the distinction between lexicon and sentence but their respective contribution to the meaning of a construction.
- The relation between formal and conceptual semantics shows up in the contribution of selection restrictions on the fillers of argument positions of a logical form: selection restrictions reflect the contribution of conceptual semantics in the instantiation of a logical form.
- The stronger conceptual restrictions are imposed on the selection of fillers of argument slots of logical forms, the more emphasis is put on conceptual structures in the meaning of the logical form: selection restrictions are a measure of how much of the meaning of possible arguments of a verb is contained in the meaning of the respective verb and consequently, how 'conceptual' or 'formal' the meaning of a verb is.
- Instead of a divide between conceptual meaning in the lexicon and truth-conditional meaning in sentences, in pervasive semantics there is a continuum of relations between truth-conditions and conceptual structure with verbs focusing truth-conditions (i.e. structure) on the one and and verbs focusing selection restrictions (i.e. content) on the other end.

Selectional Preference Strength

- Resnik [1996] approaches selection restrictions empirically as the degree to which a pair of a verb and a syntactic relationship, here direct object, constraints possible conceptual classes of fillers of the argument slots of the syntactic relationship.
- The intuition behind Resnik's selectional preference strength is that a verb-relation pair that only allows for a limited range of direct objects will have a posterior distribution of conceptual classes of direct objects in which the verb is taken into account that strongly diverges from the prior distribution of conceptual classes of direct objects in which the verb is not taken into account.
- In order to quantify the degree of restrictions in a verb-relation pair, the distribution of generalizations of direct objects to conceptual classes for a particular verb-relation pair is compared to the distribution of direct object classes over all verbs.
- Technically, this is achieved by calculating the relative entropy (the Leibler-Kullback divergence) D of two distributions, the prior distribution $P(c|r)$ and the posterior distribution $P(c|v,r)$.
- The parameters $P(c|r)$ and $P(c|v,r)$ can be estimated from the corpus frequencies of tuples (v,r,a) and the membership of nouns a in Wordnet classes c (disambiguation is avoided by splitting the frequencies equally among all Wordnet classes for a).
- The Selectional Preference Strength *SelStrength* of a pair of verb and syntactic relation is calculated as the difference in the entropy of the distribution of fillers of the syntactic relation with and without considering the verb. For all classes of nouns in C, the posterior distribution is multiplied with the logarithm of the ratio of the posterior distribution and the prior distribution.

(7)

$$\begin{aligned} SelStrength(v,r) &= D(P(c|v,r)||P(c|r))) \\ &= \sum_{c \in C} P(c|v,r) log \frac{P(c|v,r)}{P(c|r)} \end{aligned}$$

- The *selectional association* between a particular conceptual class c, a verb and a syntactic relation can be expressed in terms of the ratio of the selectional preference strength of the particular class c and the overall selectional preference strength of the verb-relation pair (the contribution that a class c makes to the overall selection preference strength of the verb-relation pair).

(8)

$$SelAssoc(v,r,c) = \frac{P(c|v,r)log\frac{P(c|v,r)}{P(c|r)}}{S(v,r)}$$

- The *selectional preference* between a verb, a relation and an argument head is defined as the maximal selectional association of the verb, the relation and any conceptual class c that the argument can instantiate.
- Resnik's approach relies on Wordnet for the generalization from head nouns to classes, but it is important to note that selection restrictions can be induced without lexical resources by using e.g. co-occurence for the generalization step (Erk et al. [2010]).

Predictions

- Given the selection preference measure, we expect that if application, support and inclusion are different conceptual relations, the difference shows up in terms of different selectional preference strength.
- We can measure the relation between formal and conceptual semantics in considering selectional strength of conceptual relations against the insensitivity of logical forms to conceptual coherence.
- In our examples, we predict that conceptual relations are ordered according to their selectional preference strength, from strong to weak: $SUPPORT > APPL > IN$.
  - *IN* in *einlagern* does not involve conceptual restrictions which are not already captured by the truth-conditions of geometrical inclusion: for putting an object in a store, it does not matter which concept is associated with the object to be stored as long as the geometry of the stored object can be included in the geometry of the store.
  - *APPL* in *überdachen* involves a relevant conceptual restriction on the objects standing in the application relation which is not captured by the truth-conditions of geometrical inclusion: the direct object must have an above region with distinct boundaries.
  - *SUPPORT* in *unterstützen* does not only involve conceptual constraints on the objects which stand in the support relation but also requires to take into account the additional concept of gravity. *unterstützen* requires appropriate direct objects to be possible subject to the laws of gravity and to provide a below region.

Linguistic grounding of conceptual semantics

- According to our proposal, if conceptual relations manifest linguistically in the strength of selection restrictions and selectional association, conceptual predicates may be considered as a stepping stone towards the linguistic exploration of conceptual meaning. In our approach, conceptual meaning can be defined linguistically without reference to conceptual structures in the first instance. Instead, our conception of conceptual meaning paves the way to a classification of concepts based on empirical observations (for p-verbs see e.g. Rüd [2012], Springorum et al. [2012]), where conceptual predicates are labels for degrees of selection preference strength.
- The bridging of formal and conceptual semantics which we propose thus does not pertain to bridging a gap but rather to a combination of formal and distributional methods, with selection restrictions bridging the two.

5 Summary and Outlook

- We introduced a pervasive approach to semantics which does not involve a structural distinction between lexicon and sentence.
- We proposed that the relation between formal and conceptual semantics can be measured out in terms of selectional preference strength, a measure which can be established without lexical resources.
- We proposed an empirical measure to test our theoretical expectations on corpus data and to motivate the use of conceptual relations in word meaning. Support comes from first proof-of-concept corpus studies and also from work in computational semantics where selection restrictions have been shown to be indicative for verb classification (e.g. Schulte im Walde [2003]).

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