Sublexical bridging of formal and conceptual semantics

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Overview

- We perceive of the gap between formal and conceptual semantics which this Workshop adresses 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.
- 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 the semantics of a verb shows up as selection restrictions on possible fillers of argument slots of the verb and in the combination of the roots of the verb.
- We propose a statistical approach to selectional preference strength as a measure on the relation between formal and conceptual semantics.

1 Pervasive semantics

1.1 Overview

- 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 (morphological complex) words is not reconstructed in the lexicon but in the syntax.
- 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, stock, mounting) can be identified with the insertion into different contexts (Roßdeutscher [2013a]) and thus be reconstructed in a principal manner.

1.2 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]).

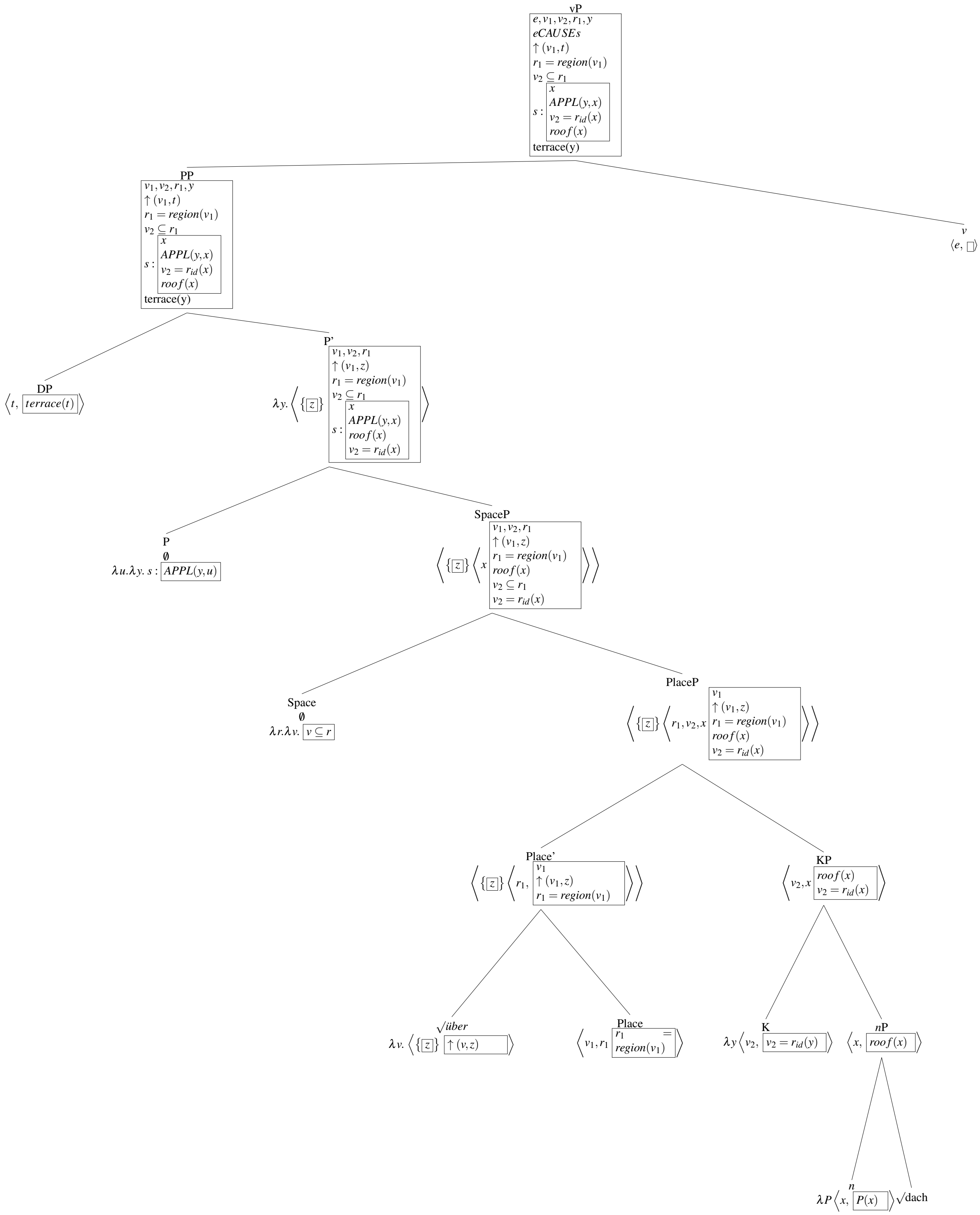
1.3 Ingredients of pervasive semantics

- 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) 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
  - v introduces events: e
  - P introduces states: s
  - n introduces individuals: x
  - $Place$ introduces regions (sets of bounded directed vectors): r
  - $K(ase)$ introduces Eigenspace-vectors: r_{id}
  - Dir introduces Faces: f

2 Examples

2.1 überdachen

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



In the reconstruction (1) of *eine Terrasse überdachen*, 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 with the conceptual relation of application. The conceptualization of SpaceP with *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.

- 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.

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

b. **eine Terrasse unterdachen*
   a terrace over.prfx.roof

c. **einen Keller überdachen*
   a basement over.prfx.roof

d. *eine Terrasse mit Dachpappe überdachen*
   a terrace with roofing felt over.prfx.roof

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

2.2 unterstützen

In (3) *ein Dach unterstützen*, SpaceP is conceptualized by P with the relation *SUPPORT*.

- 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 *somebody*))
- The geometrical relation involved in (3) is a relation of contact of an object x with a region r (in this example a face f, which is a subsort of regions): $x@r \rightsquigarrow (r_{id}(x) \bigcap r \neq \emptyset))$
- $start(v)$ selects for the starting points of vectors v
- *SUPPORT* conceptualizes a geometry of contact with respect to the concept of gravity. Thus, possible fillers of argument slots and instrumental phrases are restricted with respect to the way in which gravity applies to them.

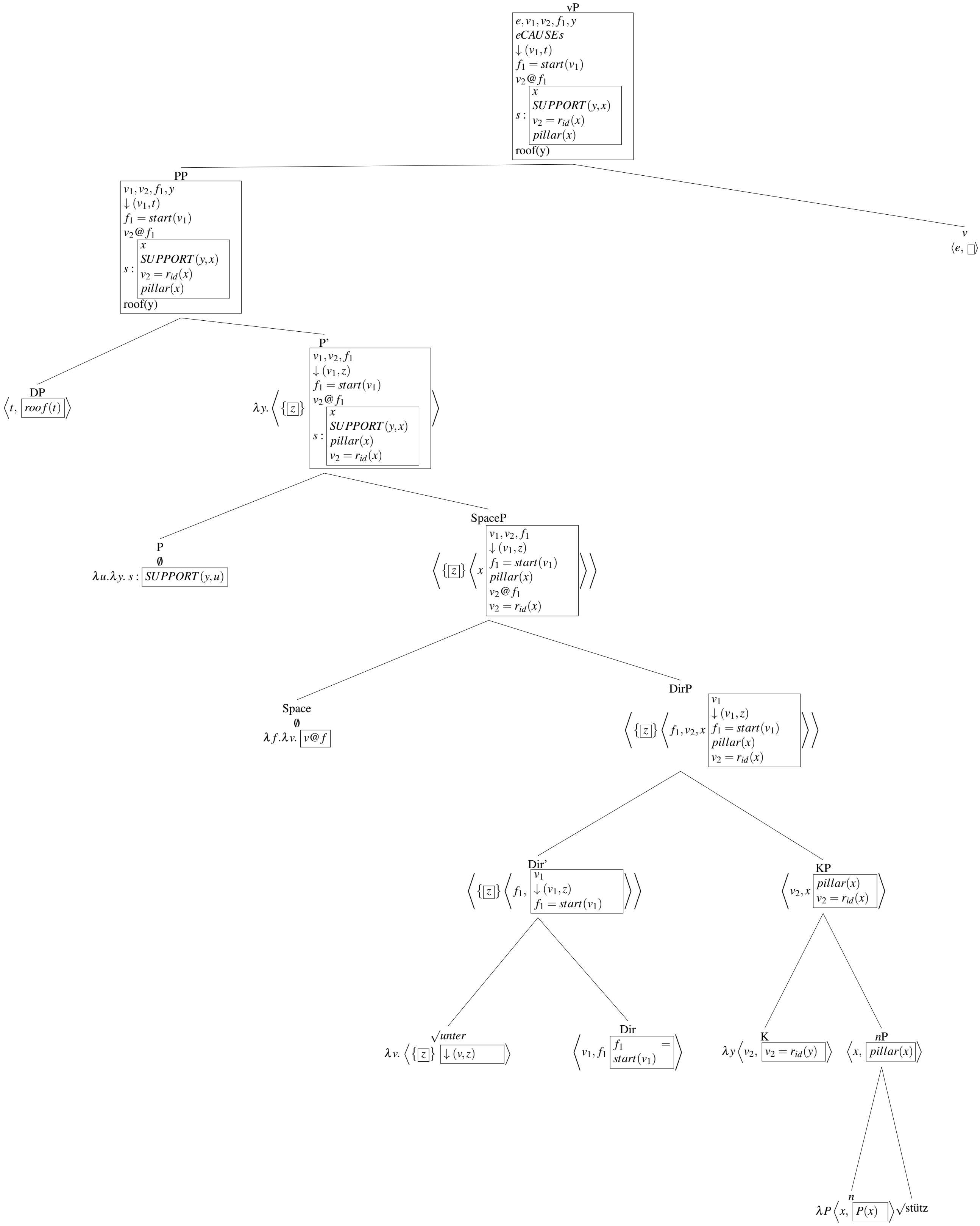
(3) a. **einen Fluss unterstützen*
   a river under.prfx.pillar

b. **überstützen*
   over.prfx.pillar

c. *ein Dach mit Holz unterstützen*
   a roof with wood under.prfx.pillar

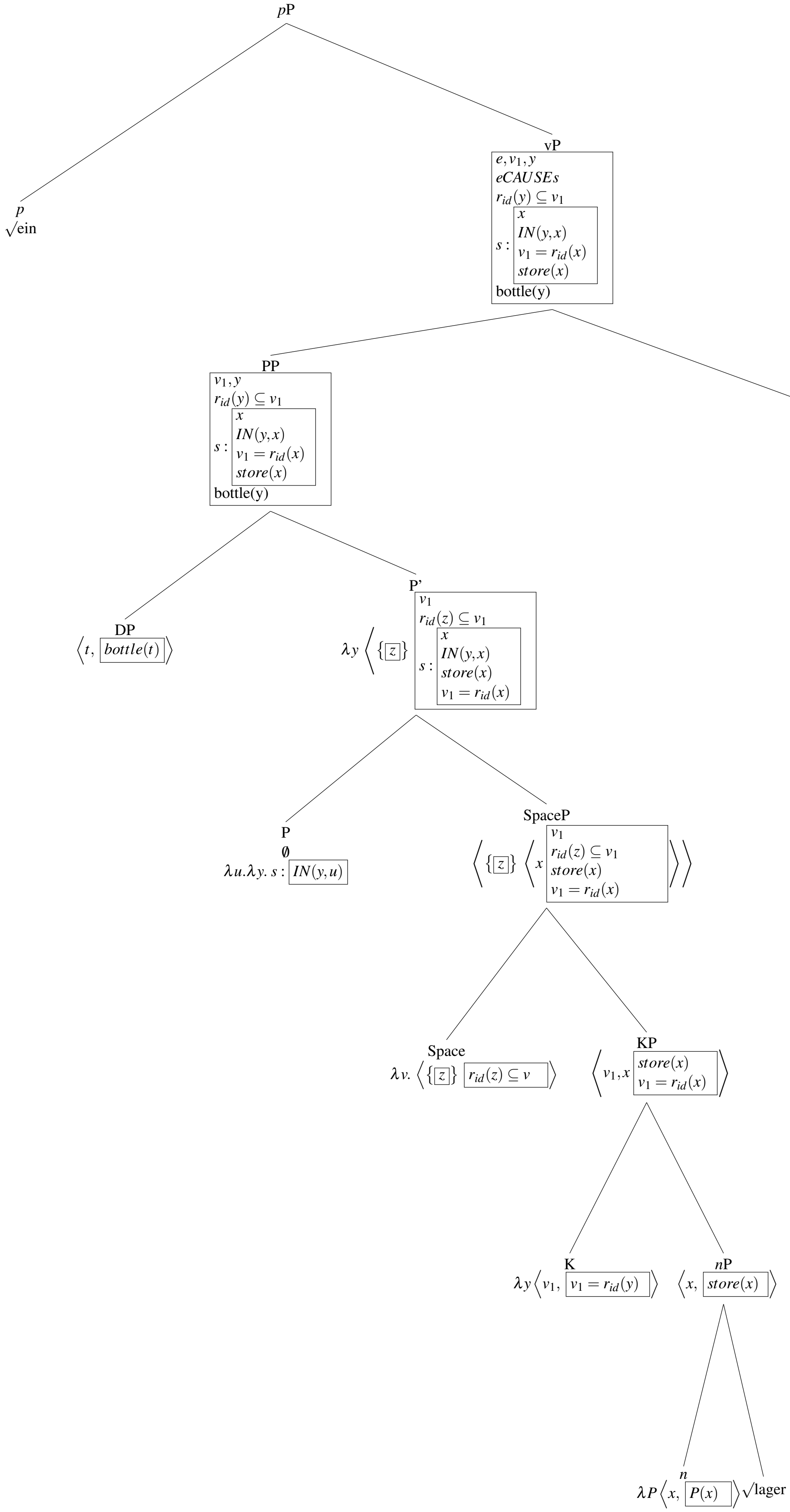
d. **ein Dach mit Kaugummi unterstützen*
   a roof with bubblegum under.prfx.pillar

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



2.3 einlagern

(4) *eine* *Flasche* *einlagern*
a bottle in.prfx.store



In the reconstruction (4) of *eine Flasche einlagern*, the conceptualization of the geometry with *IN* does not impose restrictions which are not already structurally conveyed at SpaceP.

- *IN* amounts to the geometry of the bottle to be 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 (4) 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 up.prtc.store sth. on sth.).
- The structure of (4) is slightly simplified in that the sharing of the figure between PP and *p* is not explicitly represented.

3 Measuring out the relation between formal 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.

Formal and conceptual semantics

- 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 contribution to the meaning of a construction.
- Selection restrictions (i.e. restrictions pertaining to content) are the contribution of conceptual semantics, truth-conditions (i.e. restrictions pertaining to structure) are the contributions of formal semantics.
- 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 'abstract' 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.
- In fact, 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.
- In our framework, there is a linguistic measure for the relation between formal and conceptual semantics in terms of selection restrictions, which exemplify the contribution of conceptual semantics to truth-conditions which insensitive to conceptual coherence.

Selection Restrictions

- Selection restrictions can be approached as in Resnik [1996] as the degree to which a pair of a verb *v* and a syntactic relationship *r* constrains possible conceptual classes *c* of fillers of the argument slots in the syntactic relationship *r*, e.g. the direct object relationship.

- To quantify the degree of restrictions in a verb-relation pair, the distribution of conceptual classes c for this particular verb-relation pair is compared to the distribution of classes over all verbs, given the syntactic relation r.
- Technically, this is achieved by calculating the relative entropy D of two distributions, the prior distribution $P(c|r)$ and the posterior distribution $P(c|v,r)$.
- The parameters $P(c|r)$ and $P(c|v,r)$ are estimated from the corpus frequencies of tuples (v,r,a) and the membership of nouns a in classes c.

(5)

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

- 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 selection 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).

(6)

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

- 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-occurrence 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.
- That is, we expect that there is a correlation between the conceptual relation involved in the reconstruction of word meaning and the selectional preference strength of the verb.
- In our examples, we predict that conceptual relations involved in verb meaning can be 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 and an instrumental phrase must introduce protective material in order to elaborate the nominal root.
  - *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. The truth-conditions of geometrical contact between the objects are not enough to characterize support; *unterstützen* requires appropriate direct objects to be an appropriate subject to the laws of gravity.

- 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 step-stone towards the linguistic exploration of conceptual meaning. In our approach, conceptual meaning can be defined without reference to conceptual structures in the first instance. Instead, our conception of conceptual meaning paves the way towards 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 proposed thus does not pertain to bridging a gap but rather to a combination of formal and distributional methods, with selection restrictions bridging between the two.

4 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]).

References

David Adger. *Core Syntax*. Oxford University Press, Oxford, 2003.

Artemis Alexiadou. *Functional Structure in Nominals. Nominalization and Ergativity*. John Benjamins, 2001.

Nicholas Asher. *Lexical Meaning in Context: A Web of Words*. Cambridge University Press, Cambridge, UK, 2011.

Manfred Bierwisch. Semantic form as interface. In Andreas Späth, editor, *Interfaces and Interface Conditions*, pages 1–32. de Gruyter, 2007.

Katrin Erk, Sebastian Padó, and Ulrike Padó. A flexible, corpus-driven model of regular and inverse selectional preferences. *Computational Linguistic*, 36(4):723–763, 2010.

Charles J. Fillmore. Frame semantics. In The Linguistic Society of Korea, editor, *Linguistics in the Morning Calm. Selected Papers from SICOL-1981*, pages 111–137. Hanshin, Seoul, 1982.

Fritz Hamm, Hans Kamp, and Michiel van Lambalgen. There is no opposition between formal and cognitive semantics. *Theoretical Linguistics*, 32:1–40, 2006.

Heidi Harley. A minimalist approach of argument structure. In Cedric Boeckx, editor, *The Oxford Handbook of Linguistic Minimalism*. Oxford University Press, 2011.

Heidi Harley and Rolf Noyer. Distributed morphology. *Glot International*, 4(4):3–9, 1999.

Hans Kamp and Antje Roßdeutscher. The logic and ontology of space as seen through the eyes of natural language. Lecture notes, IMS University of Stuttgart., 2005.

Hans Kamp, Josef. van Genabith, and Uwe Reyle. Discourse representation theory. In Dov M. Gabbay and Franz Guenthner, editors, *Handbook of Philosophical Logic*, volume 15, pages 125 – 394. Springer, 2nd edition, 2011.

Ingrid Kaufmann. *Konzeptuelle Grundlagen semantischer Dekompositionsstrukturen. Die Kombinatorik lokaler Verben und prädikativer Komplemente.*, volume 335 of *Linguistische Arbeiten*. Niemeyer, Tübingen, 1995.

Tillmann Pross. German medium verbs and their -ung nominalizations. In A. Roßdeutscher, editor, *Ontology and Argument Structure*, volume 10 of *SinSpec (Working Papers of the SFB 732)*, pages 24–37. University of Stuttgart, 2013.

James Pustejovsky. Type construction and the logic of concepts. In Federica Busa, editor, *The Language of Word Meaning*, Studies in Natural Language Processing, chapter 7, pages 91 – 123. Cambridge University Press, Cambridge, UK, 2001. doi: http://dx.doi.org/10.1017/CBO9780511896316.009.

Malka Rappaport Hovav and Beth Levin. Building verb meanings. In Miriam Butt and Willi Geuder, editors, *The projection of arguments: Lexical and compositional factors*, pages 97–134. CSLI, Stanford, 1998.

Philip Resnik. Selectional constraints: an information-theoretic model and its computational realization. *Cognition*, 61:127–159, 1996.

Antje Roßdeutscher. German *-ung*-formation. An Explanation of Formation and Interpretation in a Root-Based Account. *Linguistische Berichte*, Sonderheft 17:101 –132, 2010.

Antje Roßdeutscher. Particle verbs and prefix verbs in german: Linking theory versus word-syntax. *Leuvense Bijdragen*, 97, 2011.

Antje Roßdeutscher. Hidden quantification in prefix and particle verbs. In *Proceedings of Sinn und Bedeutung 16*, volume 2, pages 513 – 526, Utrecht, 2012. MIT WPL.

Antje Roßdeutscher. A Syntax-Semantics Interface for P-Elements in German verbal constructions. In Antje Roßdeutscher, editor, *Spatial prepositional roots in verbal constructions*, volume 11 of *SinSpec (Working Papers of the SFB 732)*. University of Stuttgart, 2013a.

Antje Roßdeutscher. Denominal spatial prefix-verbs revisited. In Antje Roßdeutscher, editor, *Spatial prepositional roots in verbal constructions*, volume 11 of *SinSpec (Working Papers of the SFB 732)*. University of Stuttgart, 2013b.

Antje Roßdeutscher. When roots license and when they respect semantico-syntactic structure. In Artemis Alexiadou, Hagit Borer, and Florian Schäfer, editors, *The Syntax of Roots and the Roots of Syntax*. Oxford University Press, Oxford, to appear.

Antje Roßdeutscher and Hans Kamp. Syntactic and semantic constraints in the formation and interpretation of ung-nouns. In Artemis Alexiadou and Monika Rathert, editors, *Nominalisations across Languages and Frameworks*. Mouton de Gruyter, Berlin, 2010.

Stefan Rüd. Untersuchung der distributionellen Eigenschaften der Lesarten der Partikel 'auf' mittels Clustering-Methoden. Master's thesis, IMS, University of Stuttgart, 2012.

Sabine Schulte im Walde. *Experiments on the Automatic Induction of German Semantic Verb Classes*. PhD thesis, Institut für Maschinelle Sprachverarbeitung, Universität Stuttgart., 2003. AIMS Report 9(2).

Sylvia. Springorum, Sabine Schulte im Walde, and Antje Roßdeutscher. Automatic classification of german *an* particle verbs. In *Proceedings of LREC-2012*, Istanbul, 2012.

Michael Starke. Nanosyntax: A short primer to a new approach to language. *Nordlyd*, 36(1):1–6, 2009.

Barbara Stiebels. Complex denominal verbs in german and the morphology-semantics interface. *Yearbook of Morphology*, pages 265–302, 1998.

Peter Svenonius. Limits on p: *filling in holes* vs. *falling in holes*. *Nordlyd*, 2:431–445, 2003.

Lisa Travis. *Parameters and Effects of Word Order Variation*. PhD thesis, MIT, 1984.

Dieter Wunderlich. Lexical decomposition in grammar. In Markus Werning, Wolfram Hinzen, and Edouard Machery, editors, *Oxford Handbook of Compositionality*, pages 307–327. Oxford University Press, 2012.

Joost Zwarts. Vectors as relative positions: A compositional semantics of modified pps. *Journal of Semantics*, 14:57–86, 1997.

Joost Zwarts. Prepositional aspect and the algebra of paths. *Linguistics and Philosophy*, 28:739–779, 2005.

Joost Zwarts and Yoad Winter. Vector space semantics: A model-theoretic analysis of locative prepositions,. *Journal of Logic, Language, and Information*, 9:169 – 211, 2000.