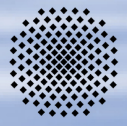

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Bridging formal and conceptual semantics

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IMS IV 28/10/2015

Formal vs. Conceptual Semantics:

“Over the last decades, truth-conditional semantics has proven successful in offering detailed analyses for how the meanings of composite expressions can be derived from the meanings of their parts.
Still, when it comes to the meanings of lexical items it is generally agreed that one has to take recourse to mental concepts and conceptual structures opening up the possibility of grounding meaning in human cognition.
This raises the question of whether conceptual structures, which are clearly internal, can be reconciled with the referential / truth-conditional approach - how might conceptual structures be made to dovetail with truth-conditional semantics?”

(CfP, Workshop on conceptual structures and truth-conditional semantics, Semantics and Philosophy in Europe 8, ZAS Berlin)

Bridging the gap is a hot topic

Workshops in 2014/2015:

- Bridging Formal and Conceptual Semantics (SFB 991, Düsseldorf)
- Conceptual structures and truth-conditional semantics (ZAS Berlin)
- Linguistic versus Non-Linguistic Knowledge (SFB 833, Tübingen)
- Formal Semantics Meets Cognitive Semantics (Nijmegen)
- Also: Compositional Distributional Semantics

This talk presents in broad strokes one of our contributions that is developed in full detail in Pross and Roßdeutscher (2015)

The gap between formal and conceptual semantics I

(1) Peter ate the slides of this talk.

- (1) is grammatical
- (1) has truth-conditions (thus, is formally meaningful)
- But something about (1) is weird.
- Syntax and formal semantics are insensitive to the weirdness – *conceptual* incoherence – of (1)
- Conceptual coherence/incoherence appears when the meaning of words is considered
- Decomposition of lexical meaning 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)).

Focus of this talk

- Relation of formal and conceptual semantics in German denominal spatial prefix- and particle-verbs (p-verbs), e.g. *unterkellern* (build a cellar under sth.)

(2) a. *ein Haus unterkellern*
a house under.prfx.cellar

b. * *ein Flugzeug unterkellern*
an airplane under.prfx.cellar

c. * *ein Haus überkellern*
a house over.prfx.cellar

Example: *unterkellern*

- Semantic form for *unterkellern* (Stiebels, 1998, p. 289)

(3) Lexical entry for *unterkellern*:

$$\lambda y.\lambda x \lambda s.CAUSE(x, BECOME(POSS(y, CELLAR)))(s) \wedge$$
$$BECOME(LOC(CELLAR\ UNDER[y]))(s)$$

'something causes an object x to become an object that possesses a cellar and the cellar becomes located under x'

Conceptual word meaning vs. formal sentence meaning

- Word meaning in the lexicon is determined by flat non-compositional conceptual structures built from a set of basic concepts.
- Sentence meaning is determined by the compositional interpretation of the hierarchical syntactic structure of the sentence.
- $\Rightarrow$ Gap between formal and conceptual semantics.
- What is the relation between formal and conceptual semantics?

Constructionalist syntax

- Lexicalist perspective: word formation is a process in the generative lexicon
- Constructionalist perspective: word formation is a syntactic process, there is no generative lexicon (Hale and Keyser (1993); Marantz (1997))
- $\Rightarrow$ no structural distinction between words and sentences
- But: if the same principles of syntax apply above and below the word level, then the same principles of semantics apply below and above the word level, too
- Our SFB-project: explore the semantic consequences of constructionalist syntax (’word meaning without a lexicon’)
- $\Rightarrow$ The gap between formal and conceptual semantics cannot manifest itself in the distinction between word and sentence meaning
- What is the relation between formal and conceptual semantics?

The linguistic access to conceptual structures

- Next, I will discuss a number of examples of spatial denominal p-verbs
- It is important to note that the motivation of the structures is based on linguistic evidence (e.g. acceptability judgements) but not on assumptions about the structure and organization of human cognition.

überdachen

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

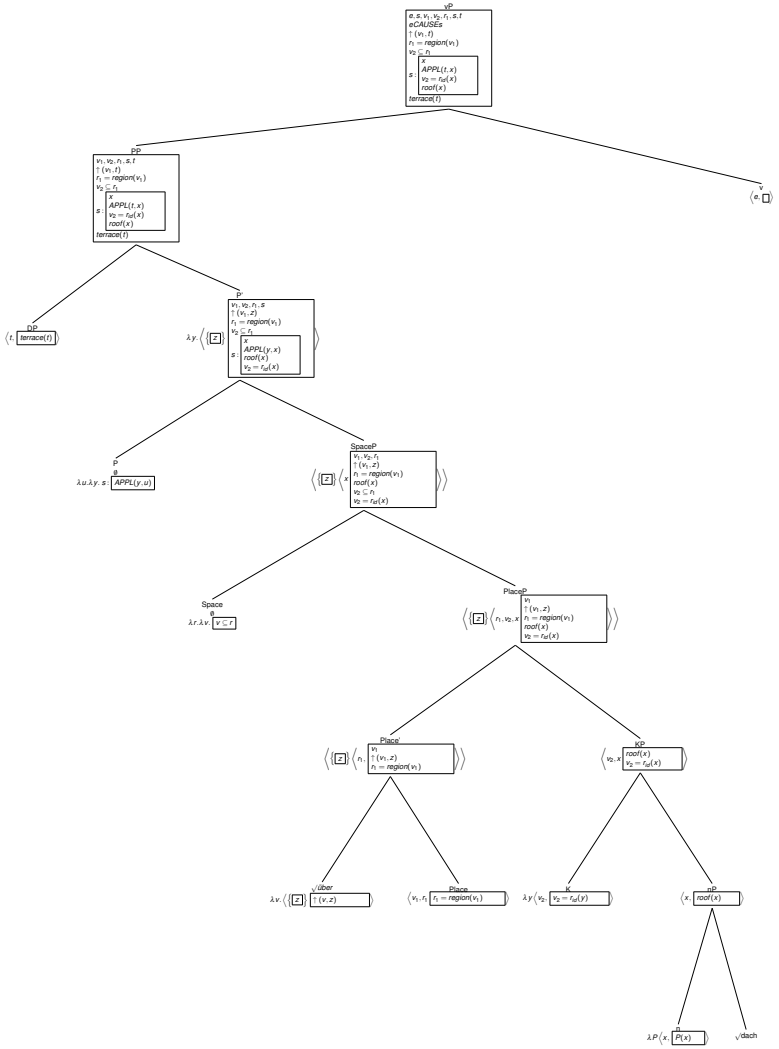
to roof a terrace

Similar: *ummauern* (to wall), *überpflastern* (to cobble), *umzäunen* (to fence in), *aufstocken* (to ramp up), *überdeckeln* (to cover with a lid), *überdecken* (to cover), *untertunneln* (to tunnel under) and *überbrücken* (to bridge).

- Two dimensions of meaning in denominal spatial p-verbs like *überdachen*
  - Conceptualization in 3-D space (here: truth-conditional vector space semantics (Zwarts (1997)))
  - Conceptualization of argument relations (here: the conceptual relation between the nominal root and the direct object)
- For *überdachen*: not any vector space object can be conceptualized as a roof or a terrace, because a roof or a terrace is more than just their geometry and location
  - A roof is “a protective covering that covers or forms the top of a building” (Wordnet search, Fellbaum (1998))
  - A terrace is a “usually paved outdoor area adjoining a residence” (Wordnet search).
- General idea: derive the spatial configuration (formal semantics), then conceptualize the spatial configuration *as* a relation of application, support, inclusion (conceptual semantics).

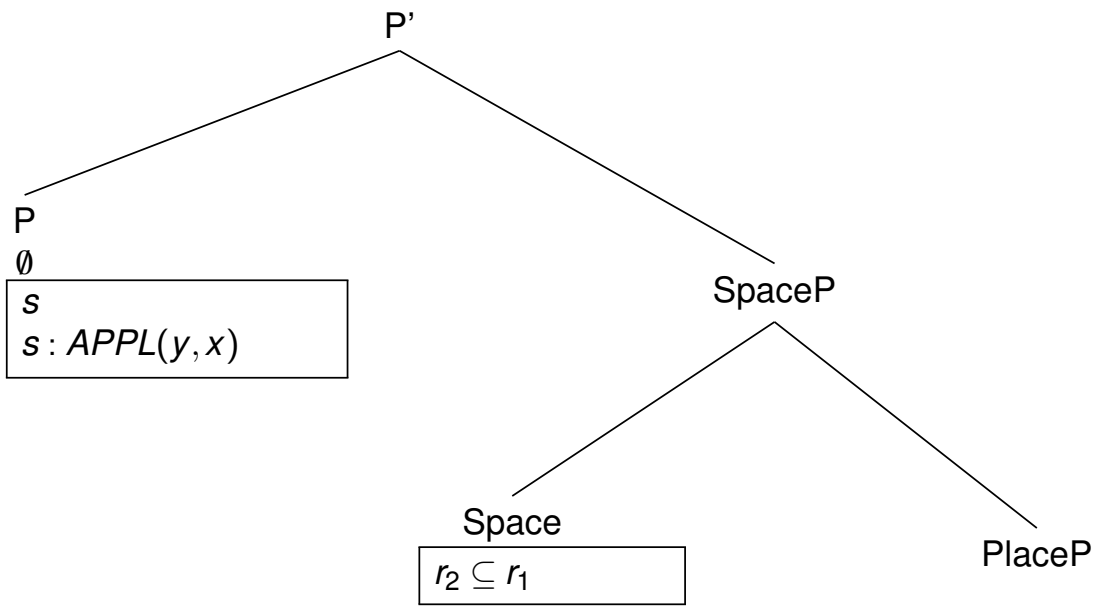
eine Terasse überdachen

(5)



Eine Terasse überdachen, Zoom

(6)



APPL involves a conceptual restriction on direct objects standing in the application relation which is not captured by the truth-conditions of geometrical inclusion: e.g. the direct object must have an above region with distinct boundaries, the direct object must be made from protective material,...

einlagern

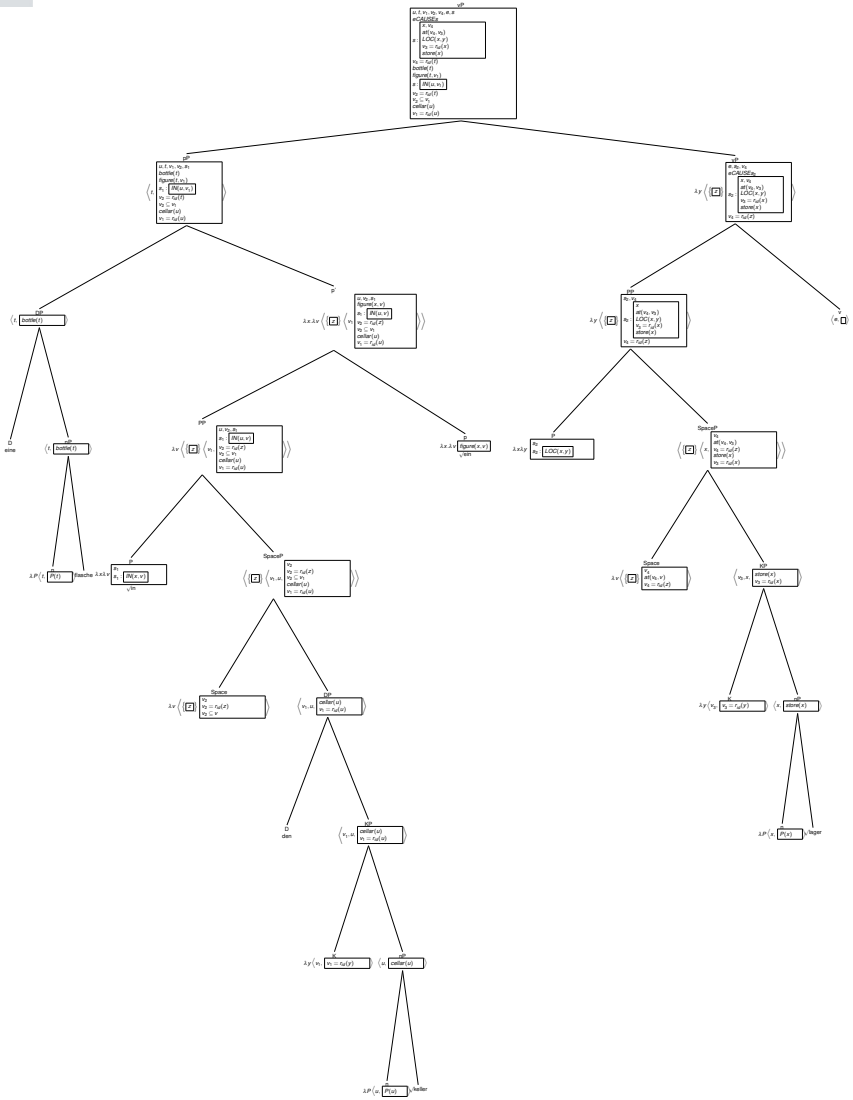
(6) *eine Flasche (in den Keller) einlagern*
a bottle (in the cellar) in.prtc.store

put a bottle in the cellar

Similar: *einsacken* (to bag sth.), *einsperren* (to cage), *einkellern* (to store), *einkerkern* (to incarcerate).

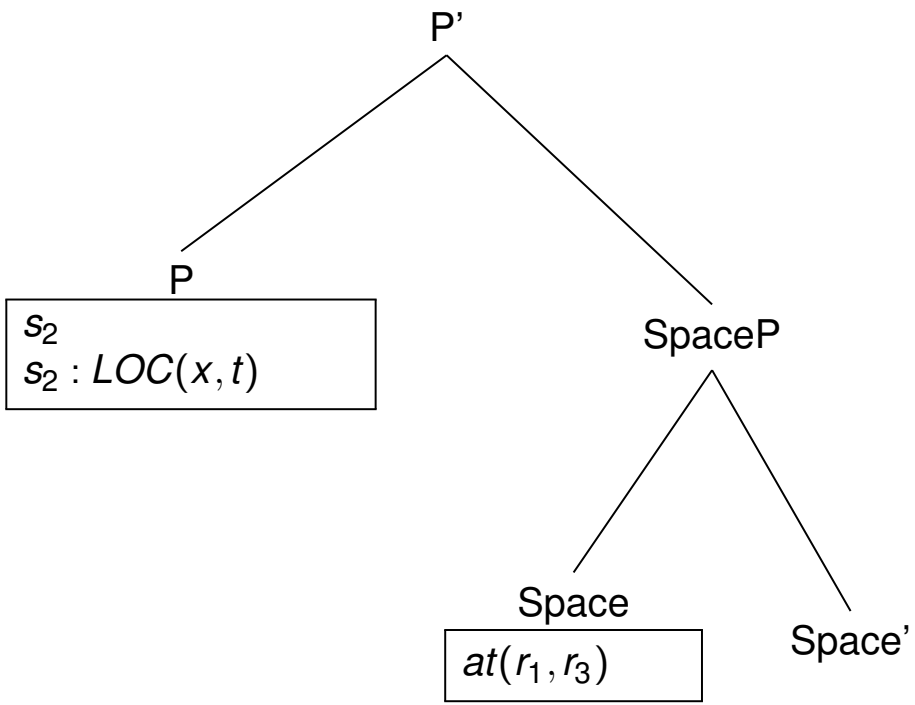
eine Flasche in den Keller einlagern

(7)



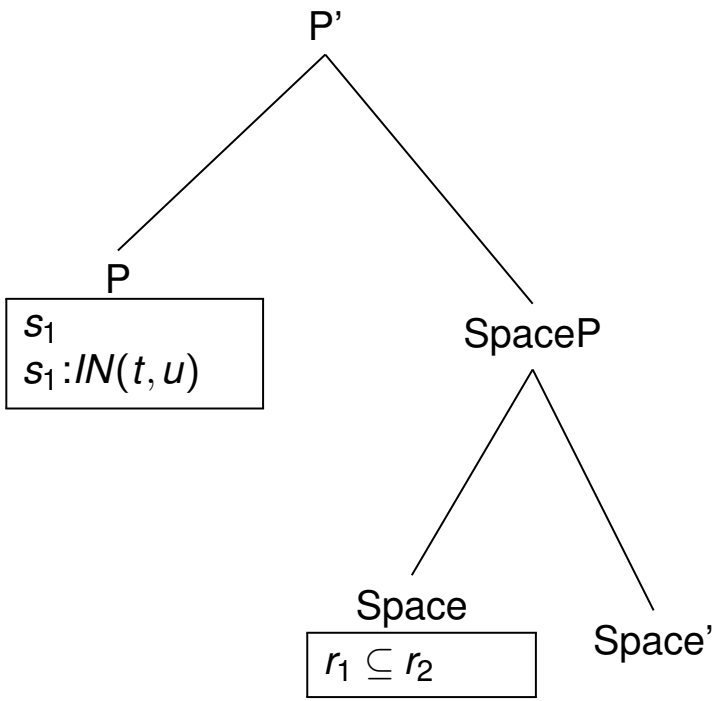
eine Flasche (ein)lagern, Zoom verb branch

(8)



eine Flasche ein(lagern), Zoom particle branch

(8)



LOC/*IN* 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.

abstützen

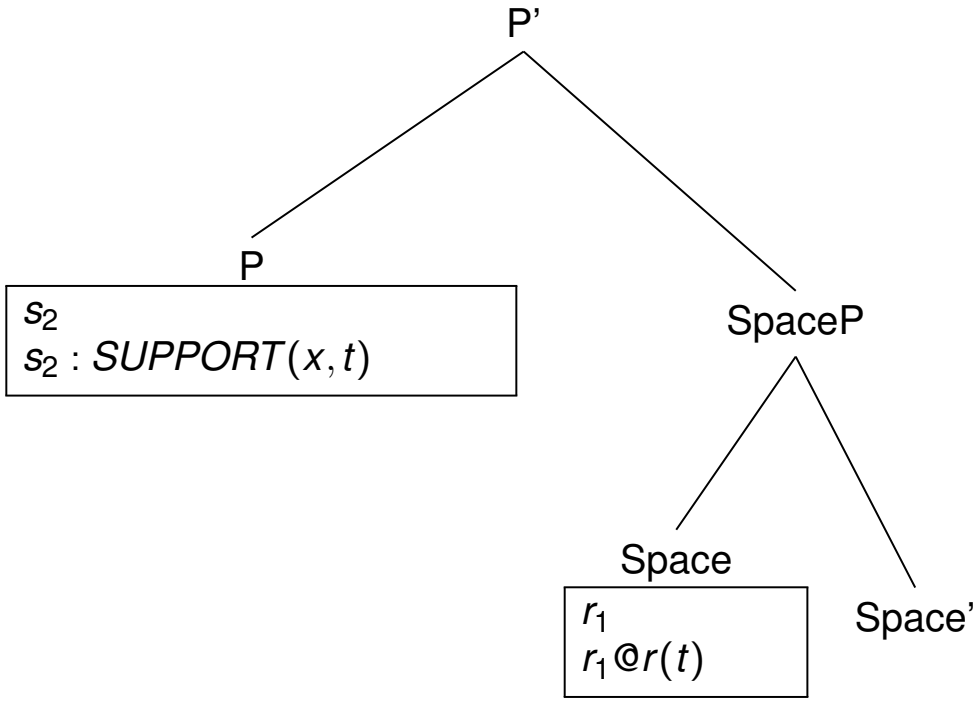
(8) *einen* *Dachstuhl* *abstützen*
a truss under.prtc.stilt

to prop up a truss

Similar: *aufbocken* (to jack up), *verstreben* (to strut), *untermauern* (to support), *unterfüttern* (to reline), *aufkanten* (to tilt sth.), *aufbahren* (to lay sb. out).

einen Dachstuhl abstützen, Zoom

(9)



SUPPORT 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 force dynamics. *abstützen* requires appropriate direct objects to provide a below region but in addition involves conceptualization of gravitation and force.

The relation between 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 employed in truth-conditional semantics are insensitive to conceptual coherence (e.g. selection restrictions on direct objects)
- 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.
- The relation of formal and conceptual semantics is a continuum with verbs such as *einlagern* focusing formal semantics and structural constraints on the one and verbs such as *abstützen* focusing conceptual semantics and selection restrictions on the other end.

Measuring out the relation of formal and conceptual semantics

- If application, support and inclusion *are* different conceptual relations, this difference should show up in terms of different selectional preference strength.
- Correlation of the conceptual relation involved in the reconstruction of word meaning and the selectional preference strength of the verb.
- Measure the relation between formal and conceptual semantics in considering the selectional strength of conceptual relations against the insensitivity of logical forms to conceptual coherence.
- We would predict (from linguistic theorizing) that conceptual relations are ordered according to their selectional preference strength, from strong to weak: $SUPPORT > APPL > LOC$.
- Thus, we could consider conceptual predicates as labels for degrees of selectional preference strength

Relative entropy as a measure of the relation between formal and conceptual semantics

- Resnik (1996): selection restrictions can be modelled 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.
- 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.

Kullback-Leibler Divergence

- The Selectional Preference Strength of a verb relative to its direct object $SPS(v,r)$ is measured with the Kullback-Leibler divergence D of two distributions
  - the prior distribution $P(c|r)$ (i.e. the distribution of direct objects without taking into account a specific verb)
  - the posterior distribution $P(c|v,r)$ (i.e. the distribution of direct objects for a specific verb)
- 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 GermaNet classes c.

(9)

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

Proof-of-Concept Study with SdeWac and GermaNet

Example verbs (from our list of 18 verbs) which reproduce our prediction nicely (manual disambiguation to spatial senses):

Verb	Concept	SPS(4)	SPS(7)
einlagern	IN	0.1	0.2
einsperren	IN	0.7	0.9
überbrücken	APPL	0.6	2.0
überdachen	APPL	0.8	4.1
abstützen	SUPP	1.3	8.0
aufbocken	SUPP	1.7	4.9

Discussion

But other verbs in our list did not so well, which is due to a combination of several factors that make the generalizations step difficult:

- Pervasive Metaphoricity (e.g. *unterstützen* (to support))
- Choice of appropriate GermaNet level: balance of fine-grainedness of types and availability of tokens
- Balance of prior and posterior distributions, given Zipf's law
  - At GermaNet level 7 both *aufbocken* (to jack up) and *aufbahren* (to lay sb. out) select only one class of direct objects (transportation vs. human) but differ remarkably in their SPS: aufbocken: 4.8 ; aufbahren: 1.7
  - For such 'symmetric' cases, only the prior probability of a direct object class determines the SPS of a specific verb (in SdeWac, organisms are more often direct objects than means of transport)
- Vertical type specificity of the GermaNet ontology
- GermaNet has a top-down hierarchy but the Resnik measure relies on the assumption that the ontological hierarchy is 'vertically' balanced.
- Transportation, humans and sausages are at the same level of GermaNet ontology but are they also similarly 'specific'?

Outlook: Distributional Semantics

- Maybe the restriction to direct objects as expressing conceptual semantics is to narrow?
- In our SFB collaboration with B9, we are trying to figure out whether clustering with distributional contexts does better.
- Current case study: *über* p-verbs

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Scaling Up

- Extraction of P-Verbs from SdeWac, removal of Pre/In/Suffixes
- Use SMOR to remove Umlaut, Schwa, Infinitiv Suffix from the verb root
- Use Levenshtein-Distance to find out for which verb roots we can find nouns.
- Problem: even for a Levenshtein-Distance of 1, for virtually any verb root we find one or more nouns.