Integrating lexical-conceptual and distributional semantics: a case report.

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1 Overview

- A theory of lexical representation is key to compositional theories of the meaning of phrases and sentences.
- This talk investigates the relation between two approaches to lexical representation: alternation-based lexical-conceptual semantics and usage-based distributional semantics.
- Leading question: How robust are the expectations of lexical-conceptual semantics when compared against distributional semantic models?
- We address this question with a case study on the meaning of German verbs prefixed with *über* (over)
- Main insight: distributional semantics, when compared with the more traditional approach of lexical-conceptual semantics, provides a novel and exciting way to investigate the conceptual underpinnings of verb meaning in an empirically grounded and theoretically unbiased way

2 Introduction

2.1 Alternation-based lexical-conceptual semantics

- Hypothesis: "syntactic properties of phrases [like admissibility of a verb into a certain argument structure alternation] reflect, in large part, the meanings of the words that head them" (Levin and Pinker, 1991)
- For example, to explain the grammaticality of verbs in the conative construction, i.e. *She cut at the bread* vs. **She broke at the bread*, it has been proposed that the relevant distinction is of a conceptual nature: *cut* is a verb of motion, contact and causation whereas *break* is a verb of pure causation (Guerssel et al., 1985).
- Consequently, the concepts of motion, contact and causation must be represented in the particular meaning of a verb in a way that syntax can be sensitive to.
- When we extend the search for such syntactically represented conceptual distinctions to a wider range of verbs and constructions, a systematic and fine-grained lexical-conceptual classification of verb meaning can be induced (Pinker, 2013; Levin, 1993).
- We refer to this particular alternation-based approach of verb meaning in the following as the lexical-conceptual structure (LCS) approach to verb meaning.

2.2 Usage-based distributional semantics

- Hypothesis: "words that occur in similar contexts tend to have similar meanings", see Turney and Pantel (2010) for an overview.
- The distribution of a word's contexts are considered central to the construction of a suitable meaning representation of that word.
- A distributional semantic model (henceforth: DSM) representation of the meaning of a word is typically a point in a high-dimensional vector space, where the dimensions of the vector correspond

to context items, e.g. co-occurring words, and the coordinates of the vector are defined by the strength of these context items, e.g. co-occurrence counts.

- Contextual similarity then becomes proximity of word meanings in the vector space.
- The DSM approach to word meaning is often illustrated by appeal to intuitions like the following (see e.g. Clark (2015)): *football* is similar in meaning to *soccer* since many of the words surrounding instances of *football* within a contextual window of a sentence are the same as the words surrounding instances of *soccer*.

3   The open question for the conceptual underpinnings of verb meaning

- The adequacy of DSM representations is traditionally not determined by inspection of the DSM representation by itself (as one would do for a LCS representation) but rather by evaluating the adequacy of a DSM representation against a gold standard (or a "Downstream Task") for a given clustering or classification problem.
- But by focusing solely on the successful reproduction of a gold standard one may miss the right goal because one may well reproduce a given gold standard of classification while still there is "little understanding of the meaning components, i.e. the semantic features, relevant to analyze verb meaning" (Lenci, 2014).
- Importantly, the same difficulties with respect to the identification of the conceptual underpinnings of verb meaning arises for theoretical approaches to verb meaning like the LCS framework
- For example, Van der Leek (1996) argues that the assumption that contact and motion are required for a verb to enter the conative construction are "purely stipulative" and that "there is no explanation why verbs that express motion and contact – and not even all of them – should enter into the alternation to the exclusion of verbs that do not".
- The goal of this talk is to address the question for the conceptual underpinnings of verb meaning by combining insights and techniques of lexical-conceptual semantics and distributional semantics.

4   Comparing LCS and DSM characterizations of *über*-affixed verbs in German

4.1   Lexical-conceptual characterization of *über*-affixed verbs

- We develop our argument with a case study on German verbs affixed with the preposition *über* (over).
- We distinguish four lexical-conceptual classes of German *über*-affixed verbs, using argument structure alternations, case assignment and the licensing of PP-complements as diagnostics (for details see Appendix A)
1 TRANSFER of an object from A to B as in *überbringen* (to deliver)
2 APPLICATION of an object to another object as in *überkleben* (to paste over),
3 Movement ACROSS some obstacle as in *überspringen* (to jump over)
4 Exceeding a certain contextual standard on a SCALE provided by the base verb as in *überbewerten* (to overvalue).

4.2   Distributional characterization of *über*-affixed verbs

- We assigned up to 20 *über*-prefixed verbs to each of the four lexical-conceptual classes
- We extracted distributional vectors with 300 dimensions for the *über*-prefixed verbs and their morphologically and semantically related base verbs using the CBOW predict-model proposed by Mikolov et al. (2013) with a symmetric 5-word window.

- (Note: The vectors were extracted from SdeWac (Faaß and Eckart, 2013), a web corpus created from a subset of the DeWaC corpus. It contains about 45m sentences selected to be well-formed sentences.)
- We then computed the pair-wise cosine similarity between the distributional vectors and tried to establish a hierarchy among the computed pairwise similarities with an hierarchical agglomerative clustering algorithm, using the unweighted pair group method with arithmetic mean as linkage algorithm.
- (Note: this procedure turned out to deliver the best results with respect to conceptual coherence of clusters discussed in the next section (as compared to e.g. a combination of a count-DSM, SVD dimension reduction and k-means clustering))

4.3 Conceptual coherence in DSMs

- Manual inspection of the hierarchy output by the clustering shows that our lexical-conceptual classification is reproduced fairly well in that the verbs we assigned to different classes are by and large grouped together hierarchically (see Appendix B).
- But the interesting observation we made is that besides the four "expected" clusters, the clustering also produced the additional fifth cluster in (1)
- In (1), verbs which we classified differently in our lexical-conceptual approach are clustered together (we abbreviate as follows: TRANSFER (t), SCALE (s), ACROSS (a) APPLICATION (ap)).

(1)   The unexpected OVERPOWER-cluster of über-prefixed verbs
       überrollen (overrun) (a); überrennen (overrun) (a); überschwemmen (flood, drown) (ap); überfluten (deluge) (ap); überfallen (attack) (s); überwältigen (overwhelm) (s); überkommen (be assailed by sth.) (t); übermüden (overfatique) (s); überfahren (knock down) (a); überfressen (overeat) (s); überschütten (spill s.th. on s.o.) (ap); überhäufen (heap on) (ap);

- Did the additional cluster come about by "accident" or does it identify an additional semantically cohesive subclass of *über*-verbs which we were not able to detect with the diagnostic tools we employed?
- The dimensions produced by predict-DSMs do not correspond to actual words (but can be thought of as soft clusters of context items Levy and Goldberg (2014)) and thus are not interpretable by humans.
- Thus, to find out more about why the verbs in (1) were clustered together, we approximated the vector representations of the *über*-verbs in the fifth cluster with their ten "nearest neighbours" in the vector space
- (Note: we identified proximity in space of two vectors with their dot product as in Levy and Goldberg (2014))
- Consider the ten nearest neighbours for the base verb *rennen* ('to run') in (2) and the derived verb *überrennen* ('to overrun') from the cluster (1) in (3).

(2)   *rennen* (to run) BASE
       springen.V schnappen.V zurennen.V hüpfen.V wegrennen.V schreien.V brüllen.V schleichen.V
       jump   snap   towards-run hop   run-away   scream   yell   creep
       aufspringen.V schreiend.A
       jump-up   screaming

(3)   *überrennen* (to overrun) DERIVED

Horde.N belagern.V Truppe.N Übermacht.N Streitmacht.N einmarschieren.v stürmen.V
hord   besiege   troop   superiority   force   invade   assault

erobern.V besiegen.V umzingeln.V
conquer   defeat   surround

- The DSM-representation of *(über)rennen* shows, and this generalizes to the verbs that were clustered together in (1), that the verbs in (1) were not clustered together by accident but rather because they share a common conceptual core.
- The *über*-prefixed verbs describe unforeseeable events of overpowering instances of (natural) forces exertion.
- Thus, it appears that DSM representations reflect conceptual commonalities between verbs similar to Levin's semantically cohesive subclasses
- But conceptual commonalities like the 'overpowering'-concept underlying (1) are difficult to target in the LCS-framework because nothing in the lexical-conceptual semantics of *rennen* or *über* indicates the possibility of a meaning shift like the one exemplified by *überrennen* through *über*-prefixation.

5   A more fine-grained look at the DSM representation of complex verb meaning

- Why and how does the DSM approach to lexical meaning detect, capture and represent semantic effects like the meaning shift exemplified by *überrennen* that are difficult to target in the LCS-framework?
- To approach this questions, we adopted an additive model of the composition of DSM representations (see Baroni et al. (2014) for an overview) and represented the meaning shift that results from the composition of a base verb with its prefix by the difference between the base verb vector and the prefix verb vector.
- Using the same method of nearest neighbour approximation as in the previous section, we rendered transparent the "shift" vector that results from subtracting the DSM representation of a base verb from the DSM representation of the corresponding *über*- prefixed verb.
- (Note: we did not try to learn one general DSM representation of the prefix *über* because a general DSM representation would have smoothed out the meaning of *über*)

5.1   Two modes of composition

5.1.1   Rigid composition

- Consider first the approximated DSM representations of the base verb *kleben* (to glue) (4), the derived verb *überkleben* (to cover) (5) and the shift vector in (6).

(4)   *kleben* (to glue) BASE
      aufkleben.V   ausschneiden.V Klebeband.N festkleben.V **bekleben.V**   verkleben.V
      glue.on.PRTC.glue out.PRTC.cut   tape   fix.glue   be.PRXF.glue fix
      tropfen.V ankleben.V bemalen.V   abwischen.V
      drop   on.glue   be.PRFX.paint wipe-off

(5)   *überkleben* (to cover) DERIVED
      Aufkleber.N **bekleben.V**   Plakat.N Schriftzug.N Aufschrift.N **kleben.V aufkleben.V**
      sticker   be.PRXF.glue poster   letters   label   glue   on.PRTC.glue

bedrucken.V Aufdruck.N prangen.V
be-print   logo   be-respleshdent

(6) *über* (over) SHIFT
vorgenommen.A Bundesarchiv.N Bürgerbegehren.N   Rüstungsexport.N Freiheitsstrafe.N
planned   federal-archive petition-referendum export-of-arms   prison-punishment
Umbenennung.N erfolgt.A Kürzung.N staatlich.A irreführend.A propagandistisch.A
re-naming   done   short-cut state   misleading   propaganda

- The combination of the verb *kleben* and the prefix *über* yields the APPLICATION meaning predicted
  by our lexical-conceptual classification, in which the meaning of the prefix and the derived verb is
  the same as the meaning of the preposition and the base verb in the locative alternation, see (7).

(7) a. Peter überklebte   den Kratzer mit einem Aufkleber.
         Peter over-PRFX.glue the scratch with a   sticker.
         'Peter over-pasted the scratch with a sticker'
     b. Peter klebte den Aufkleber über   den Kratzer.
         Peter paste the sticker   over.PREP the scratch.
         'Peter pasted the sticker over the scratch'

- Hypothesis: when there are some shared nearest neighbours of the base vector and the derived
  vector (indicated by the bold face neighbours in (4)/(5)), the shift vector is basically noise and the
  meaning of the derived verb is compositional.
- When the salient dimensions of meaning of the preposition and the verb do not change through
  composition, we call the composition of the meanings of the preposition and verb "rigid" (in that
  the meaning of the complex construction is not sensitive to context)

5.1.2   Holistic composition

- Next, consider the approximated DSM representations of the base verb *schauen* (to look) (8), the
  derived verb *überschauen* (to survey) (9) and the shift vector in (10).

(8) *schauen* (to look) BASE
gucken.V starren.V anstarren.V   anblicken.V blicken.V anschauen.V angucken.V grinsen.V
peer   stare   at.PRTC.stare look-at-so. look   look-at-s.o. peer-at-s.o. grin
lächeln.V reinschauen.V
smile   look-into-s.th

(9) *überschauen* (to survey) DERIVED
überblicken.V **Komplexität.N Tragweite.N** Gestirn.N Mannigfaltigkeit.N Einbildungskraft.N
survey   complexity   bearing   luminary complexity   imagination
Ansehung.N **Gesamtzusammenhang.N** Materie.N   unüberschaubar.A
reputation totality   interstellar-matter unmanagable

(10) *über* (over) SHIFT
Komplexität.N Berücksichtigung.N Folgewirkung.N **Gesamtheit.N** Verflechtung.N
complexity   taking-into-account consequence   totality   interconnection
Umwelteinwirkung.N   Beeinträchtigung.N **Tragweite.N** Funktionsträger.N
environment-consequence impairment   bearing   administrator
Differenzierung.N
differentiation

- Hypothesis: when the overlap in nearest neighbours is greater between derived and shift vector ((9)/(10)) than between base and derived vector ((8)/(9)), this indicates that the meaning of the derived verb is figurative and that the meaning of the prefix *über* and the base verb *schauen* in combination is different from the meaning these words have in isolation.
- Tellingly, in contrast to *überkleben* (5) where the base verb *kleben* is among the nearest neighbours of the derived verb *überkleben*, the base verb *schauen* (to look) is not among the nearest neighbours of the derived verb *überschauen* (to survey) (9)
- We call such a meaning of a complex expression that cannot be reduced to the meanings of its constituents "holistic".
- (Note: A quite similar holistic effect of meaning composition is involved in the fifth cluster of verbs of 'overpowering' (1), where the distributional characterization shows that the expected change of location reading is by and large replaced by the dislocated meaning of an unforeseeable event of (natural) force.)

5.2   A linguistic reflex of holistic composition

- Interestingly, the holistic semantic effect of prefixing *schauen* with *über* is linguistically reflected in that the locative alternation with *überschauen* is restricted.
- The meaning of the base verb *schauen* licenses the realization of the Ground argument with a PP-complement (11-a) but not as the direct object of the holistic interpretation of the prefix-construction (11-b)

(11)   a.   Der Mann schaute über   die Stadt.
              the man   look   over.PREP the city
              'The looked over the city.'
        b.   ?Der Mann überschaute   die Stadt.
              the man   over-PRFX.see the city
              'The man overlooked the city.'

- Conversely, the holistic interpretation of the prefix verb *überschauen* licenses the Ground argument only as a direct object (12-b) but not as a PP complement (12-a)

(12)   a.   *Der Mann schaute über die Komplexität des   Problems.
              the man   look   over the complexity   the.GEN problem
        b.   Der Mann überschaute   die Komplexität des   Problems.
              the man   over-PRFX.look the complexity   the.GEN problem
              'The man surveyed the complexity of the problem.'

- The restrictions on the locative alternation with *überschauen* are of a conceptual nature.
- In (11), *schauen* is a perception verb that can be complemented with a PP specifying the perceptual space (i.e. that the subject has a view over the city).
- Because in (12) a spatial specification of the field of view with a PP is ungrammatical, the relevant dimension of meaning in which *überschauen* is interpreted is no longer spatial (as is required for a verb to participate in the locative alternation).
- Instead, the composition of the verb and the prefix induces a holistic semantic effect by which the meaning of the prefix-verb is dislocated to a dimension of meaning not present in the prefix or the base verb in isolation.
- While such intuitions about the "dislocation" or "shift" of the conceptual underpinnings of a word's meaning are quite plausible, these intuitions are difficult to capture in terms of lexical operations
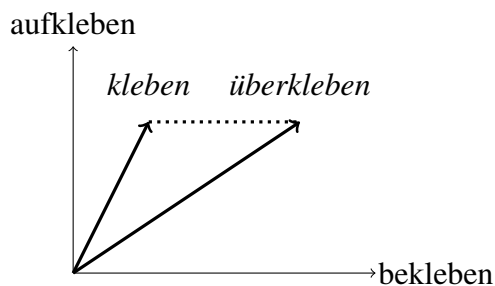
on the LCS of the base verb.

- But the way in which we phrased our intuitions by considering meaning as a space in which shifts or dislocations of meanings can take place hints towards the possibility that DSM representations are better suited to make precise the difference between rigid and holistic composition.
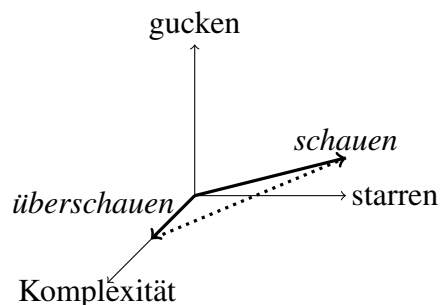
5.3 Approaching rigid and holistic composition with a non-technical understanding of "meaning spaces"

- To foster an intuitive understanding of how DSM representations capture the fact that meaning components denoted by the dimensions of a pair of vectors remain (mostly) unchanged in one case, but change in others, we frame the contrast between rigid and holistic composition in a figurative understanding of meaning as a vector space.
- (Note: the following elaborations are neither intended as formally accurate explanations of DSM representations – in particular, we use nearest neighbours as approximations of dimensions – nor as lexical representations of word meaning in the traditional sense. Instead, we use the idea of meaning being represented in a vector space in a non-technical way to highlight what we believe is the specific "surplus" of DSM representations of meaning when compared against LCS-style analyses.)
- Consider first the rigid composition of *kleben* and *über*, where the base verb and the derived verb have salient nearest neighbours in common, i.e. the bold-faced nearest neighbours in (4)/(5).
- For the sake of illustration, assume that we characterize the meaning of the base and derived verb with two of these shared salient nearest neighbours – (*bekleben* (to paste sth. up) and *aufkleben* (to glue sth. on)) – and interpret the vectors associated with these neighbours as the dimensions of the meaning of the base and derived verb.
- Second, in the holistic case (8)/(9), the derived verb and the shift vector but not the base and derived verb share salient dimensions of meaning.
- Again, assume for the sake of illustration that we characterize the base verb *schauen* with its two most salient nearest neighbours *gucken* ('to peer') and *starren* ('to stare') and the derived verb with its most salient nearest neighbour *Komplexität* (''complexity) and that we use the vectors associated with these nearest neighbours as the meaning dimensions of the base and derived verb.
- The figures (13) and (14) visualize the meaning spaces characterized by these assumptions, where we represent the contribution of *über* according to our additive composition model as a dotted vector.

(13)   **rigid meaning composition**

(14)   **holistic meaning composition**

- In (13) the meaning components denoted by the dimensions of the vectors remain (mostly) unchanged, but are deleted or overwritten in (14).
- In (13) the composition of *über* and the base verb retains the original meaning dimensions (i.e. new dimensions already present in the meaning of the base verb are added)
- In (14) the meaning dimensions of the base verb are replaced with new ones not present in the meaning of the base verb.

- Figuratively speaking, the derived verb *überkleben* lives in the same meaning space in which the base verb lives.
- In contrast, *überschauen* lives in a region of the meaning space different from that in which the constituents *überschauen* is composed of are located.
- In sum, whereas rigid composition is dimension-preserving and the meanings of *über* and *kleben* are the meanings these words have in isolation, holistic composition is non-dimension-preserving and the meaning composed of *über* and *schauen* cannot be decomposed to the meanings the preposition and the base verb have in isolation.

6   Summary

- The relation between the LCS and DSM approach to verb meaning is more complex than it appears at first glance, and we think we have just scratched the surface.
- Importantly, the differences between the two are not just of a technical but also of a conceptual nature; the high dimensionality of the meaning space encoded in a DSM captures aspects of verb meaning that cannot be detected and represented with lexical frameworks like LCS (which focus on specific meaning dimensions like event or argument structure).
- But precisely because the "surplus" of DSM representations of word meaning falls outside the scope of traditional lexical semantics, this raises the question for how phenomena like the holistic meaning composition in (14) can be operationalized in a way that is compatible with established frameworks of lexical semantics like LCS (and notably, the same question arises for the more well-researched case of adjective-noun composition, see e.g. Asher et al. (2016); McNally and Boleda (2017)).
- Given the complimentary strengths of LCS and DSM models of word meaning, we believe that a further investigation of the combination of lexical-conceptual and usage-based approaches may lead to an empirically grounded and theoretically sound theory of word meaning in its entirety.

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A   The four lexical-conceptual classes of über-verbs

- That data we use in this paper are German verbs affixed with the preposition *über*
- The basic use of *über* ('over') is as a preposition with two distinct meanings (see e.g. Zwarts (2005)).
- Depending on the aspectual class of the matrix verb, an *über*-PP can refer to the direction of the motion of an accusative reference object as in (15) or to the location of a dative reference object as in (16).

(15)   Der Mann sprang über den Zaun.
     the man jump over the.ACC fence
     "The man jumped over the fence"

(16)   Das Bild hing über der Tür.
     the painting hang over the.DAT door
     'The painting hung above the door'

A.1   ACROSS

- First, when *über* is affixed to a verb as in (17), the derived verb describes a movement ACROSS some obstacle. As (15) shows, a PP complement construction with *über* is licensed with motion verbs like *springen*.

(17)   Der Mann übersprang   den   Zaun.
     the man   over-PRFX.jump the.ACC fence
     'The man jumped over the fence'

A.2   TRANSFER

- Second, when *über* is affixed to change of possession verbs like *geben* ('to give'), the prefixed verb describes the *transfer* of an object x from A to B as in (18). The argument marked with dative case identifies the location at which the transferred object x ends up. No *über* PP-complement construction is possible with the base verb (19).

(18)   Er übergab   ihr   den   Brief
     he over-PRFX.give her.DAT the.ACC letter
     'He handed her over the letter'

(19)   *Er gab den Brief über sie.
     he give the letter over her

A.2.1   APPLICATION

- A third class of *über*-affixed verbs describes the APPLICATION of an object to another object as in (20-a). This class of APPLICATION verbs is distinguished from the ACROSS class by participation in a locative alternation as in (20-a)/(20-b).

(20)   a.   Peter überklebte   den Kratzer mit einem Aufkleber.
         Peter over-PRFX.glue the scratch with a   sticker.
         'Peter over-pasted the scratch with a sticker'

b. Peter klebte den Aufkleber über   den Kratzer.
Peter paste the sticker   over.PREP the scratch.
'Peter pasted the sticker over the scratch'

A.3 SCALE

- Fourth, *über*-affixation of a verb can also be used to describe that the event denoted by the verb exceeds a certain contextual standard on a SCALE provided by the base verb, see (21). No PP-complementation with *über* is possible for the SCALE-class and the direct object receives accusative case (22).

(21) Er überbewertete   die   Aktie.
he over-PRFX.value the.ACC share
'He overvalued the share'

(22) *Er bewertete über die Aktie
he value   over the share

B The four expected clusters

- TRANSFER class (t)
- SCALE class (s)
- ACROSS class (a)
- APPLICATION class (ap)

(23) TRANSFER übergehen (pass s.th.over) (a); übereignen (convey) (t); überführen (lead across) (a); übernehmen (take over) (t); überlassen (let s.o. s.th. for use) (t); überantworten (pass repsonsibility) (t); übersenden (send) (t); übermitteln (transfer)(t); überreichen (hand over) (t); übergeben (hand over) (t); überweisen (trans-scribe) (t);

(24) SCALE überstimmen (outvote) (s); überrepräsentieren (overrepresent) (s); überspielen (copy) (t); überhören (miss s.th.) (a); überreizen (overexite) (s); überfordern (overstrain) (s); überstrapazieren (overstrain) (s); übertreiben (overdo) (s) ; übersteigern (surmount) (s); überzeichnen (make burlesque) (s); überdrehen (overwind) (s); überspitzen (exaggerate) (s); überhöhen (inflate) (s); überladen (overload) (s); überfrachten (overcharge) (s); überschätzen (overestimate) (s); überbewerten (overrate) (s); übersehen (overlook) (a); überwiegen (outweigh) (s); überbuchen (overbook) (s);

(25) ACROSS übersetzen (translate) (t); überliefern (pass down) (t); überschreiben (transfer) (t); überlesen (skip) (a); überblättern (page over) (a); überfliegen (fly across) (a); überarbeiten (overwork) (s); überschreiten (overstep) (a); übertreten (cross) (a); überspringen (jump over) (a); überschauen (survey, overlook) (a); überkreuzen (cross) (a);

(26) APPLICATION überhängen (cover by hanging s.th.) (ap); überstreuen (cover with sprinkles) (ap); überstäuben (cover with dust) (ap); übergießen (douse) (ap); übersprühen (cover by spraying) (ap); überstreichen (cover with paint) (ap); übermalen (cover by painting) (ap); überkleben (paste over)(ap); überziehen (cover with a coat) (s); übertünchen (cover with whitewash) (ap); überdecken (cover) (ap); überlagern (overlay, interfere) (ap); überbauen (build s.th. across s.th.) (a); überklettern (climb over) (a); überwachsen (overgrow) (ap); übersäen (reseed) (ap); überragen (tower above)(a);