Representing force dynamics at the syntax-semantics interface

Workshop Formal Semantics Meets Cognitive Semantics, Nijmegen
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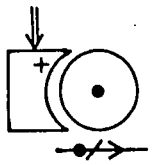
January 2015

1 Introduction

- We perceive of the division of the discipline of semantics as manifesting itself in the different structuring of meaning in formal, lexical and cognitive semantics
- In formal semantics, sentence meaning is determined by the compositional interpretation of the syntactic structure of the sentence
- In lexical semantics, word meaning is determined by conceptual structures built from a set of basic concepts or fundamental constituents of meaning ('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]))
- Example semantic form for kill: $\lambda y.\lambda x\lambda e.(ACT(x) \wedge BECOME\ DEAD(y))(e)$
- In cognitive semantics, the fundamental concepts of meaning are grounded in cognitively motivated 'image schemas', structures of experience independent of concepts (Johnson [1987], Lakoff [1988])
- Example schema from (Talmy [1988]) for "The ball's hitting it made the lamp topple from the table."



- Acknowledging differences in scope and motivation and grossly generalizing,
  - Formal semantics is concerned with how meaning is derived compositionally from sequences of words but not what the fundamental constituents of meaning are and how they pattern in words
  - Lexical semantics is concerned with how the fundamental constituents of meaning pattern in words
  - Cognitive semantics is concerned with the fundamental constituents of meaning but not with how meaning is derived compositionally from sentences nor with how the fundamental constituents of meaning pattern in words
- In this talk, we report on our ongoing efforts to bring these different perspectives on semantics together:
  - First, we propose that 'image schemas' are indicated at the syntax-semantics interface but not in the lexicon, thus directly linking the structural constraints on meaning established by formal semantics to the cognitive content of semantic primitives.
  - Second, we propose to enrich formal semantics with a fine-grained ontology (in the sense of Jackendoff [1988]) and a relational, context-sensitive definition of semantic roles (opposed to absolute definitions of semantic roles in terms of theta-grids)
- With Talmy [1988], we share the assumption that forces and their interaction (force dynamics) is a central concept involved in the meaning of natural language descriptions of events.

- We motivate our proposal with the linguistic encoding of forces and their dynamics (where our source of inspiration is Copley and Harley [2014a,b]) and Force-Recipient/Ground relations (based on Svenonius [2003], Zwarts and Winter [2000], Zwarts [2005], Beavers [2011]) in the compositional interpretation of the patterns exhibited by the German examples in (1) involving the force verb *ziehen* (pull).

(1) a. *Peter zieht die Rübe aus der Erde.*
Peter pull the carrot out the soil
Peter pulls the carrot out of the soil.

b. *Peter zieht den Zahn.*
Peter pull the tooth
Peter extracts the tooth.

c. *Peter zieht an der Rübe.*
Peter pull at the carrot
Peter pulls at the carrot.

d. *Peter zieht die Schraube an.*
Peter pull the screw at
Peter tightens the screw.

Framework

1.1 Syntax-Semantics Interface

- In pervasive or constructivist syntax approaches such as Distributed Morphology (overview: Harley and Noyer [1999]), Nanosyntax (overview: Starke [2009]) or Exoskeletal Syntax (Borer [2005, 2013]), 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
- Roots combine with features to build larger linguistic elements according to the same syntactic and semantic principles which are at work above the word level
- The syntactic structures we employ are not ad-hoc but follow the prinicples of minimalist syntax of phrase structure + move and merge (e.g. Chomsky [1995], Adger [2003]), incorporation is governed by the head movement constraint (Travis [1984]).
- Syntactic structures are motivated by syntactic and semantic acceptability diagnostics (e.g. modification or phrase completion/diminishment)
- Functional heads in the syntax are responsible for the introduction and modification of argument slots according to minimalist approaches 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])
- For the semantic interpretation of syntactic structure, we use Discourse Representation Theory (Kamp et al. [2011]) where composition of DRSs is governed by applying λ-conversion and consequent DRS merge at each node of the syntactic structure.

1.2 The Building Blocks of Meaning

The syntax-semantics interface is complemented with two general principles for the introduction of conditions on discourse referents

- The first principle is what we call the identification principle
- Thematic conditions imposed on a particular argument slot are chained together with a generalization of Kratzer [1996]'s event identification principle:
- The term *identification* refers to an application of the abstract identification principle in (2), where α, β, γ are arbitrary types.

(2) a. $f : \langle \alpha, \langle \beta, \gamma \rangle \rangle + g : \langle \beta, \gamma \rangle \rightarrow h : \langle \alpha, \langle \beta, \gamma \rangle \rangle$
b. Kratzer's example for Agent introduction
$\lambda x \lambda e.AGENT(e,x) + \lambda e.feed(the-dog,e) \rightarrow \lambda x \lambda e.AGENT(x,e) \wedge feed(the-dog,e)$

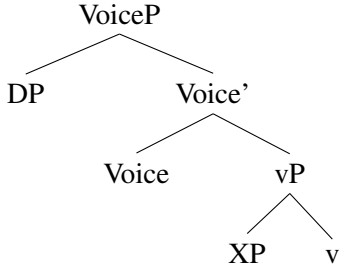
- The second principle is what we call the conceptualization principle

- Functional heads in the syntax are responsible for the introduction and predication of a particular sort of discourse referents ("ontological building blocks")
  - v introduces events: e
  - $force$ introduces forces: f
  - $Place$ introduces regions (sets of bounded directed vectors): r
  - $Scale$ introduces scales (sets with a linear order): s
  - Discourse referents are introduced by establishing a conceptual relation between the introduced discourse referents and the complement XP of the functional head which introduces the discourse referent.
  - The term *conceptualization* refers to the application of one of the following predication conditions:
    - a force f is conceptualized as that force f of which e is an exertion: vP + force-denoting $pP \rightarrow eEXERTf$
    - a region r is conceptualized as that region r to which a force f is directed: $forceP$ + region-denoting source-preposition $PP \rightarrow fGOALr$
    - a region r is conceptualized as that region r at which a force f attaches: $forceP$ + location-denoting source-preposition $PP \rightarrow fATTACHr$
    - a scale s is conceptualized as that scale s on which the magnitude of a force f is located: $forceP$ + scale-denoting $ScaleP \rightarrow fLOCs$
  - Similar conceptualization conditions for e.g. $SUPPORT$, $APPLICATION$, $POSSESSION$ and Aktionsart are discussed in Pross and Roßdeutscher [2014a,b,c]
  - Conceptualization provides a link to the account of fundamental meaning that cognitive semantics associates with image schemas such as $GOAL$, $EXERT$ or $SUPPORT$.
  - From the viewpoint of formal semantics, the function of conceptualization is to existentialize that discourse referent in relation to which a new discourse referent is introduced.

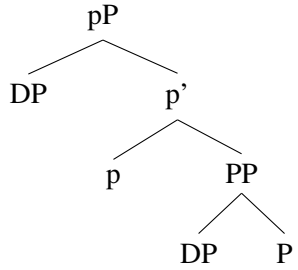
1.3 Functional Split of V and P

- Against these background assumptions, we make the following suggestion:
- Events are to V are what forces are to P, or: V conceptualizes events and P conceptualizes forces.
- Kratzer [1996] famously proposed a functional split in VPs by introducing an additional projection 'Voice' responsible for the introduction of the external argument of a verb, see the schematic structure in (3)
- Following Ramchand [2008]'s terminology, we call the external argument of a verb in active voice the $INSTIGATOR$ of the event described by the verb.
- Svenonius [2003] made some initial steps towards establishing a similar split of functions in prepositional phrases by introducing a projection p responsible for the introduction of the Figure of a preposition relative to a ground PP, see the structure in (4)
- We propose to extend the idea of p to a full parallelism between V and P by introducing a functional projection forceP corresponding to vPs (5)

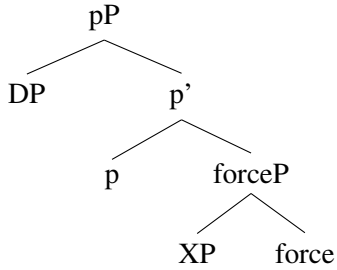
(3) Kratzer's Split V



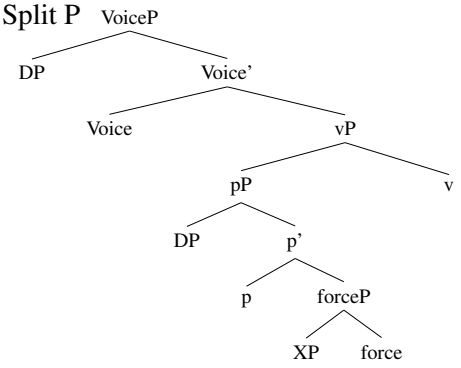
(4) Svenonius' Split P



(5) Force-Based Split P



(6) Combination of Split V and Force-Based Split P



- We reconstruct the variation in the meaning of the root $\sqrt{zieh}$ in terms of differences in the structure (6) related to the:
  (a) conceptualization of events based on the variation of the linguistic patterns of Figure and Ground realization (the contribution of the complement XP of v) against the background of force-dynamics patterns.
  (b) conceptualization of forces based on the variation of the linguistic patterns of prepositional descriptions (the contribution of the complement XP of force) against the background of force-dynamic patterns.

2 Image Schemas

2.1 Figure Ground Pattern

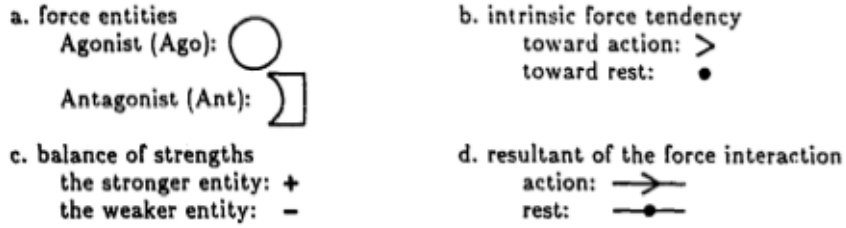
Example from Talmy [2000]:

(7) a. The pen lay on the table
b. The pen fell off the table

- In (7), the pen specifies the object that functions as Figure and the table the object that functions as Ground.
- A Figure is a moving or conceptually movable entity whose path, site, or orientation is conceived as variable
- The Ground is a reference entity, one that has a stationary setting relative to a reference frame, with respect to which the Figure's path, site, or orientation is characterized
- Following Beavers [2011], we call the Figure a Force-Recipient.

2.2 Force Dynamics

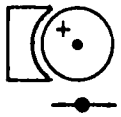
(8)



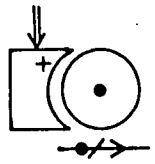
We use two force dynamic patterns:

(9) a. The shed kept standing despite the gale wind blowing against it. [Talmy, 1988, p. 55]
b. The ball's hitting it made the lamp topple from the table. [Talmy, 1988, p. 57]

- (9a) describes a steady-state force dynamic pattern in which the shed (Agonist) has an intrinsic tendency to rest which is stronger than the wind (Antagonist) opposing it (image schema: (10))

(10) 

- (9b) descibes a shifting force dynamic pattern in which the lamp (Agonist) has an intrinsic tendency to rest which is weaker than the ball (Antagonist) opposing it, thus causing the lamp to change from a state of rest to one of action (image schema: 11)

(11) 

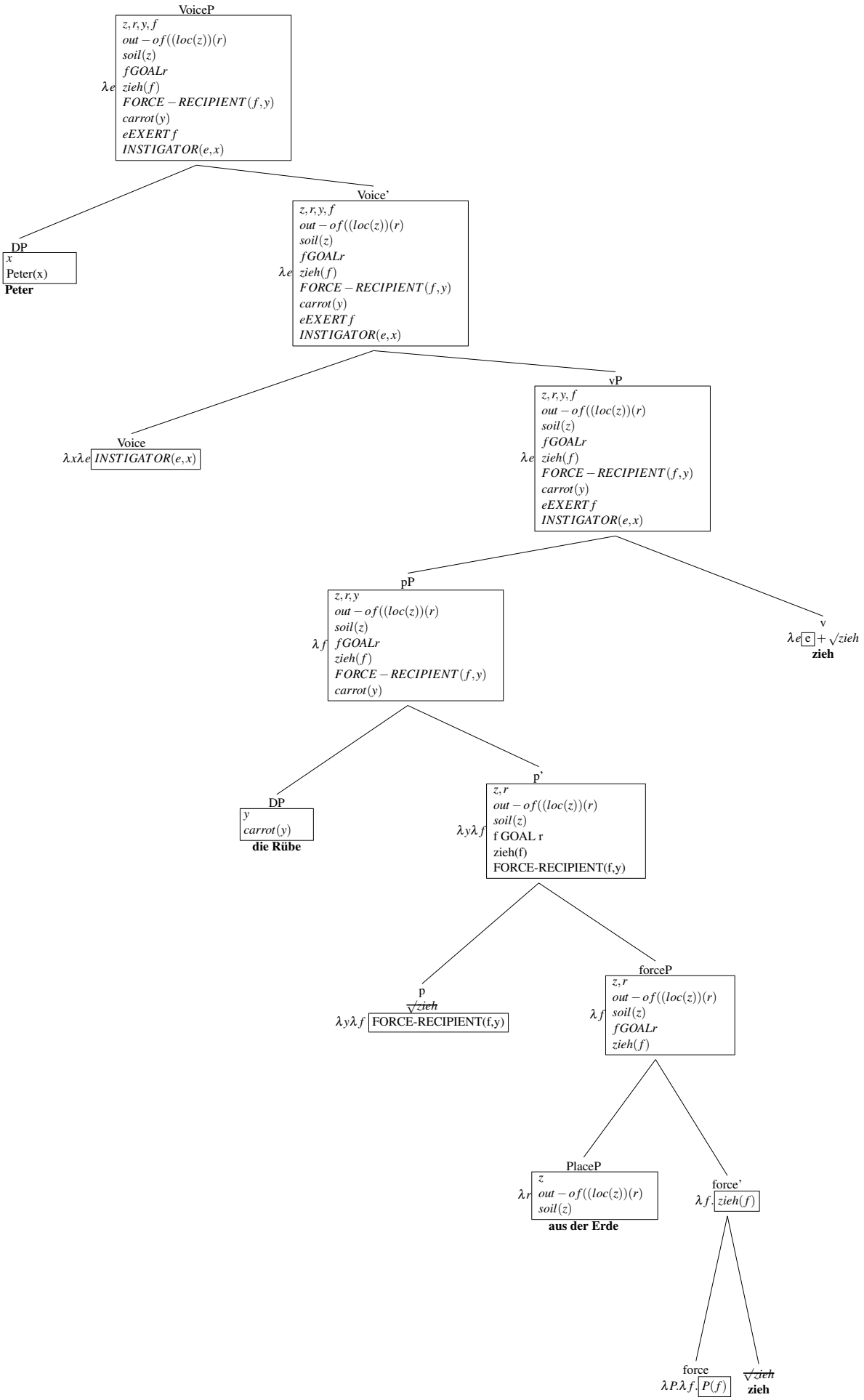
3 Reconstruction of Force Dynamic Patterns

3.1 Overt Force-Recipient and Ground; Shifting Force Dynamics

(12) *Peter zieht die Rübe aus der Erde.*
Peter pull the carrot out the soil
Peter pulls the carrot out of the soil.

- In (12), both the Force-Recipient (the carrot) and the Ground (the soil) relative to which the Force-Recipient moves when force is exerted on it are overtly realized.
- For the reconstruction in (13), we adopt the vector-space semantics of Zwarts and Winter [2000] to derive the semantics of the directional PlaceP *aus der Erde* (out of the soil) involving the source preposition *aus* (out of) as a function that maps a set of points $loc(soil)$ (the eigenspace of the soil) to its externally closest vectors v, thus specifying a "goal" region r relative to a source.
- force introduces a force f which conceptualizes r in that f is predicated between PlaceP and forceP as r being the goal of f.
- p identifies f as that force of which y (the carrot) is the Force-Recipient such that it moves relative to the ground described by the specifier of the complement XP of pP.
- v introduces an event e which conceptualizes f in that e is predicated between vP and pP as an exertion of the force f.
- Voice identifies e as that event of which x (Peter) is the Instigator relative to the Force-Recipient described by the specifier of the complement XP of vP
- The force dynamic pattern reconstructed in (13) is the shifting force dynamic pattern (9b), in which the carrot is the Agonist with a tendency toward rest which is overcome by the Antagonist Peter's pulling on it which causes the carrot to move out of the soil.

(13)


VoiceP
z, r, y, f
out − of((loc(z))(r))
soil(z)
fGOALr
λe zieh(f)
FORCE − RECIPIENT(f, y)
carrot(y)
eEXERTf
INSTIGATOR(e, x)
DP
x
Peter(x)
Peter
Voice'
z, r, y, f
out − of((loc(z))(r))
soil(z)
fGOALr
λe zieh(f)
FORCE − RECIPIENT(f, y)
carrot(y)
eEXERTf
INSTIGATOR(e, x)
Voice
λxλe INSTIGATOR(e, x)
vP
z, r, y, f
out − of((loc(z))(r))
soil(z)
fGOALr
λe zieh(f)
FORCE − RECIPIENT(f, y)
carrot(y)
eEXERTf
INSTIGATOR(e, x)
pP
z, r, y
out − of((loc(z))(r))
soil(z)
λf fGOALr
zieh(f)
FORCE − RECIPIENT(f, y)
carrot(y)
v
λe e + √zieh
zieh
DP
y
carrot(y)
die Rübe
p'
z, r
out − of((loc(z))(r))
soil(z)
λyλf f GOAL r
zieh(f)
FORCE-RECIPIENT(f,y)
p
√zieh
λyλf FORCE-RECIPIENT(f,y)
forceP
z, r
out − of((loc(z))(r))
λf soil(z)
fGOALr
zieh(f)
PlaceP
z
λr out − of((loc(z))(r))
soil(z)
aus der Erde
force'
λf.zieh(f)
force
λP.λf.P(f)
√zieh
zieh

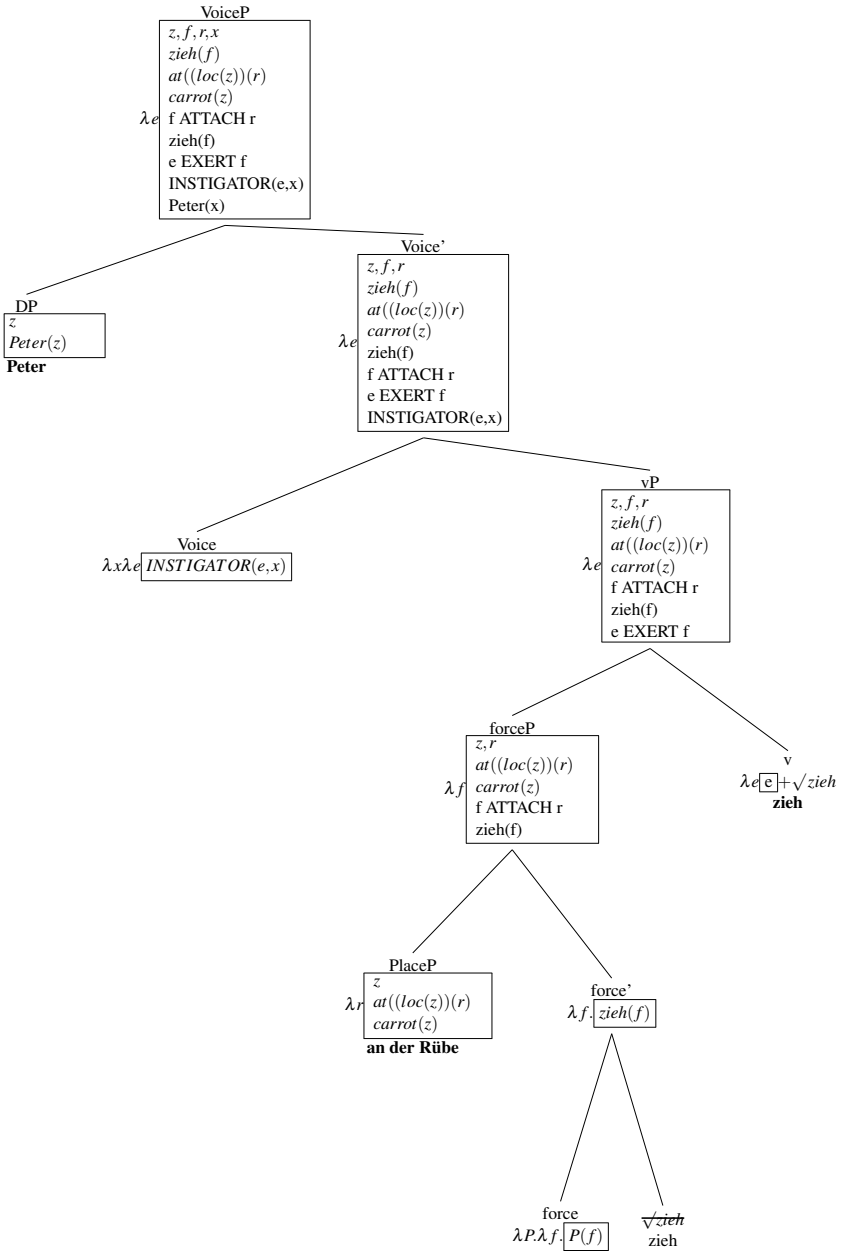
3.2 Overt Ground, No Force-Recipient; Steady-State Force Dynamics

(14) *Peter zieht an der Rübe.*
Peter pull at the carrot

Peter pulls at the carrot.

- In the conative construction the direct object of a transitive verb appears as the argument in a prepositional phrase headed by locative *an*. The conative construction is commonly understood as describing an " 'attempted action' without specifying whether the action was actually carried out or not." [Levin, 1993, p. 41].
- The preposition *at* locates the attachment region of a force in (14)
- The conative construction differs from the analysis in (13) in that it lacks a p head projecting the Force-Recipient, see (15)
- That is, the conative construction is is a defective event description in that the internal argument of the verb is not an object but a force and consequently there is no Force-Recipient in which the outcome of the exertion of force would manifest (which explains the "attempt" character of the conative construction).
- The reconstructed force dynamic pattern is the steady-state pattern in (9a) in which the Agonist (the carrot) has a tendency to rest which is stronger than the Antagonist forces exerted by Peter.

(15)

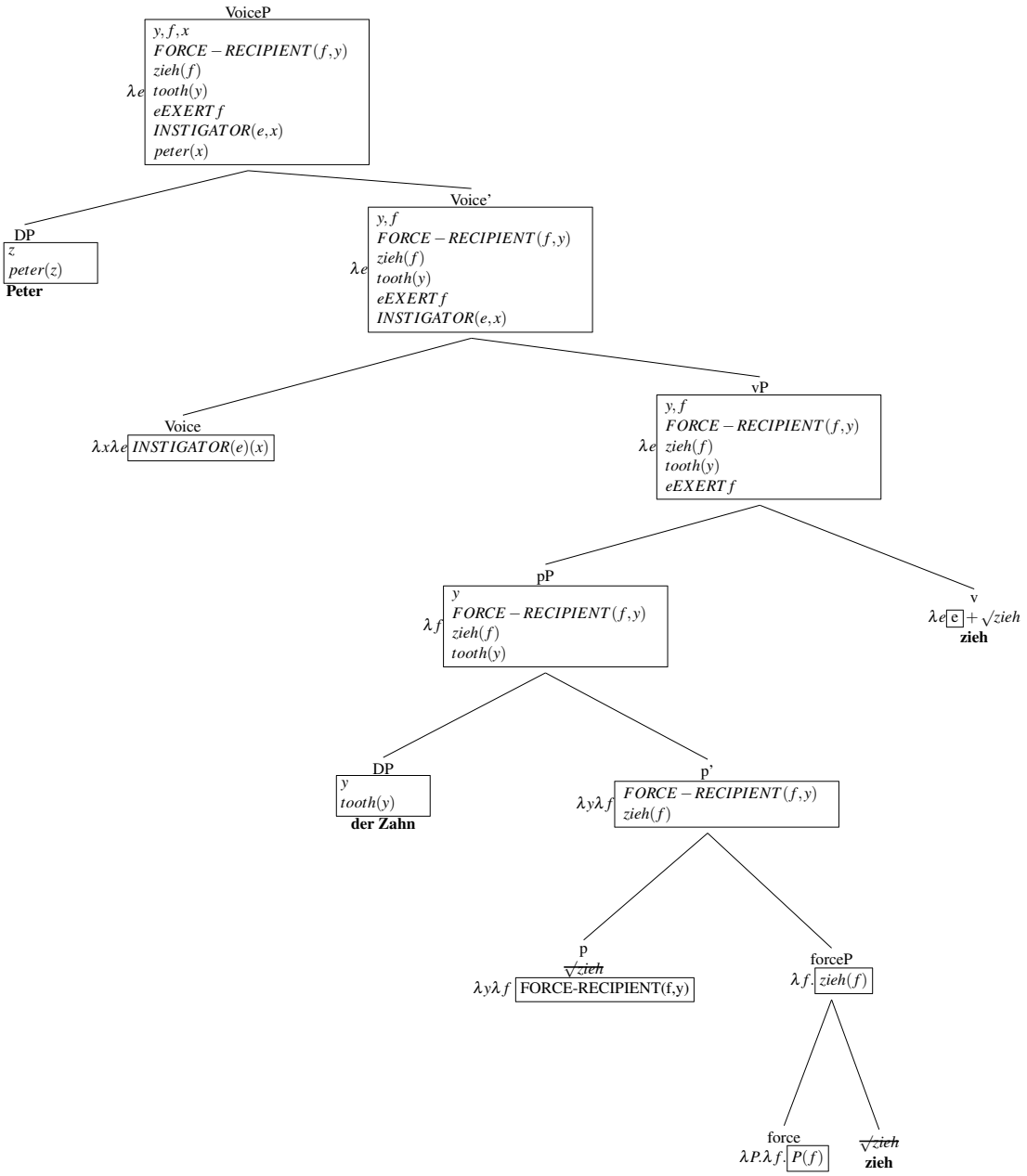


3.3 Overt Force-Recipient, No Ground; Reconstructed Shifting Force Dynamics

(16) *Peter zieht den Zahn.*
Peter pull the tooth.
Peter extracts the tooth.

- In descriptions of the type (16), no Ground is linguistically realized relative to which the tooth is a Force-Recipient, see (17)
- Nevertheless, (16) can only be understood as describing a force dynamic pattern in which the intrinsic tendency of the Agonist tooth to rest is overcome by Peter's exertion of Antagonist forces
- In fact, Talmy claims that although all "of the interrelated factors in any force-dynamic pattern are necessarily copresent wherever that pattern is involved", descriptions "pick out different subsets of the factors for explicit reference – leaving the remainder unmentioned" [Talmy, 1988, p. 61].
- Thus, the underlying force dynamic pattern is the same as for (13).
- We think that the restrictedness of the construction in (16) reflects that the force dynamic pattern must be accomodated by world knowledge, e.g. that teeth, unlike e.g. bottles have a typical location at which they rest: cp. e.g. pull the gun, pull the plug.
- Invocation of this kind of world knowledge allows for reconstruction of the force dynamic pattern and at the same time completes the Figure-Ground relation: when the tooth is a recipient of a pull-force, it moves out of the jaw.

(17)



3.4 Overt Force-Recipient, Scalar Ground: Shifting Force Dynamics

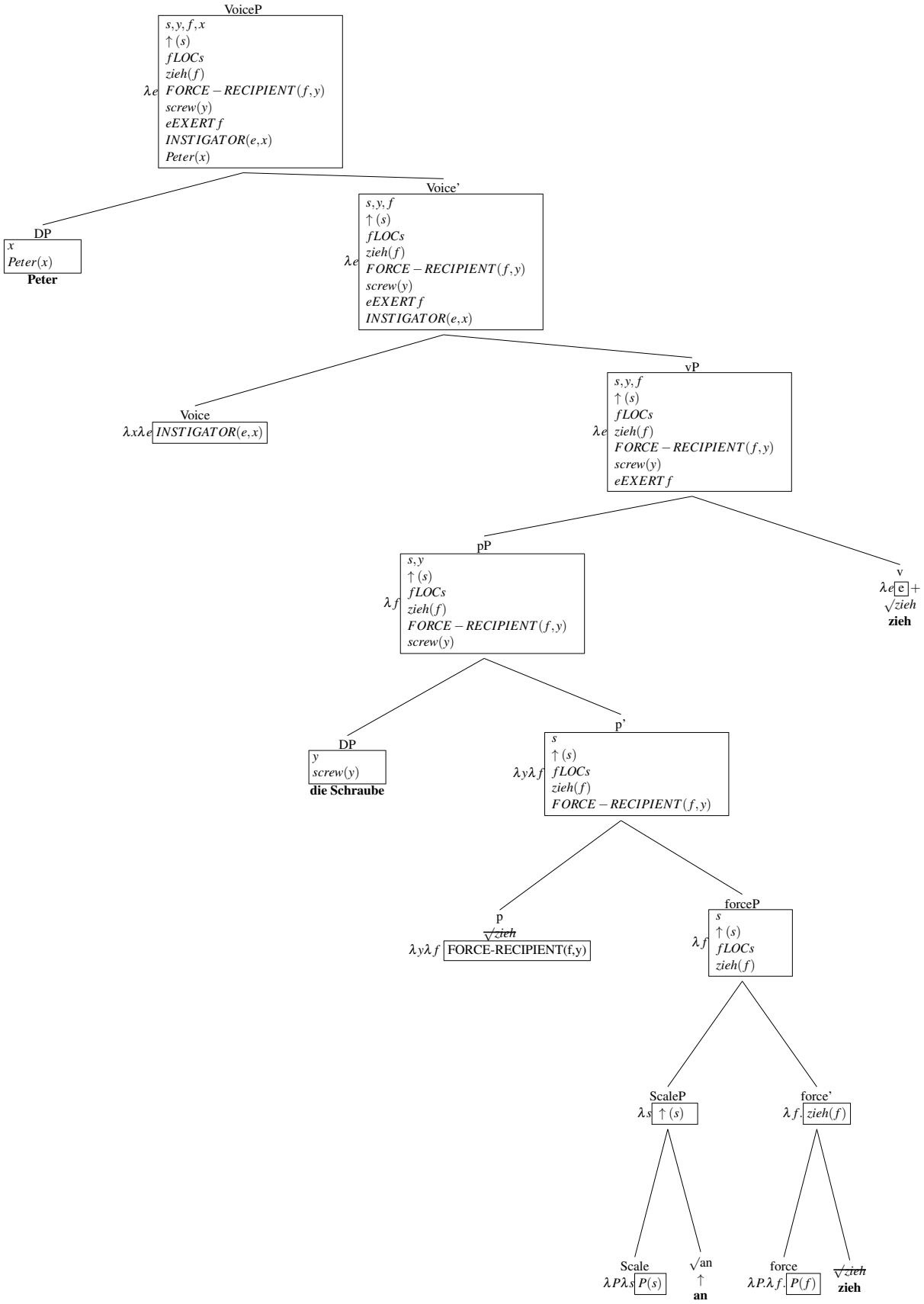
(18) *Peter zieht die Schraube an.*
Peter pull the screw up

Peter tightens the screw.

- In (18) the Force-Recipient screw is increasingly affected relative to a scale of force (more specifically, torque) induced by the particle *an*, see (19)
- *an* specifies a scale of values as '*in*creasing', a regular semantic contribution of the root $\sqrt{}$an as opposed to $\sqrt{}$ab, meaning '*de*creasing' in German.
- The particle constructions under consideration share structural properties with de-adjectival verbs such as *lengthen a rope* (discussed in Hay et al. [1999], Kennedy and Levin [2008]).
- In (18), the Agonist screw has a tendency to rest.
- *an* contributes an increase in the Antagonist force, i.e. the Antagonist becomes stronger and stronger and therewith overcomes the Agonist's tendency to rest.

- The force dynamic pattern underlying (18) is the shifting force pattern in (9b): the intrinsic tendency of the Agonist screw's torque to rest at a certain value is overcome by the Antagonist forces exerted by Peter which causes the screw to undergo change in the direction indicated on the scale (i.e. up).

(19)



Summary

- We presented a framework which relates formal and cognitive semantics in that the meaning of words and phrases is derived compositionally at the syntax-semantics interface under the assumption of a cognitively inspired theory of "building blocks of meaning", among them forces, regions and scales.

A Appendix

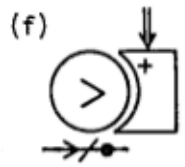
A.1 an vs. ab

(20) *Peter bremst das Fahrzeug ab.*
Peter brake the vehicle down

Peter decelarates the vehicle.

- The Resultant of Force Interaction is a decrease in the Agonist's tendency to rest.
- (20) describes a force dynamic pattern in which the Agonist has a tendency to move. *ab* contributes a decrease in the Agonist's tendency to move caused by the Antagonist force.
- Force pattern: The water's dripping on it made the fire die down.

(21)



A.2 Aktionsart and Force Verbs

See Pross and Roßdeutscher [2014c]

(22) a. *für 5 Sekunden (*in 5 Sekunden) an der Rübe ziehen*
for 5 seconds (*in 5 seconds) at the carrot pull

pull at the carrot for 5 seconds

(23) a. *die Rübe in 5 Sekunden (*für 5 Sekunden) aus der Erde ziehen*
the carrot in 5 seconds (*for 5 seconds) out the soil pull

pull the carrot out of the soil in 5 seconds

b. *den Zahn in 5 Minuten (*für 5 Minuten) ziehen*
the tooth in 5 minutes (*for 5 minutes) pull

extract the tooth in 5 minutes

c. *den Wagen (*in 5 Minuten) für 5 Minuten hinter sich herziehen*
the car (*in 5 minutes) for 5 minutes behind refl_{DAT} hither.pull

pull the car (*in 5 minutes) for 5 minutes behind

(24) *die Grenze in 5 Minuten (*für 5 Minuten) ziehen*
the border in 5 minutes (*for 5 minutes) pull

draw the border in 5 minutes

(25) *die Schraube leicht anziehen*
the screw slightly up.prtc.pull
slightly tighten the screw

(26) *den Schmutz *leicht anziehen*
the dirt *slightly up.prtc.pull
attract the dirt

(27) *den Schuh in 5 Minuten anziehen*
the shoe in 5 minutes at.prfx.pull
to put on the shoe in 5 minutes

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.

John Beavers. On affectedness. *Natural Language & Linguistic Theory*, 29:335–370, 2011.

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

Hagit Borer. *Structuring Sense (Vol. I & II)*. Oxford University Press, Oxford, 2005.

Hagit Borer. *Structuring Sense (Vol. III)*. Oxford University Press, Oxford, 2013.

Noam Chomsky. *The Minimalist Program.* MIT Press, Cambridge, MA, 1995.

Bridget Copley and Heidi Harley. A force-theoretic framework for event structure. Unpublished Manuscript,, 2014a.

Bridget Copley and Heidi Harley. A force-theoretic model. Unpublished Manuscript, Paris 8 / U Arizona, 2014b.

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.

Kenneth Hale and Samuel Jay Keyser. On argument structure and the lexical expression of syntactic relations. In Kenneth Hale and Samuel Jay Keyser, editors, *The View from Building 20: Essays in Linguistics in Honor of Sylvain Bromberger.* MIT Press, Cambridge, MA, 1993.

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.

Jennifer Hay, Christopher Kennedy, and Beth Levin. Scalar structure underlies telicity in "degree achievements". In T. Mathews and D. Strolovitch, editors, *SALT IX*, pages 127–144, 1999.

Ray Jackendoff. Conceptual semantics. In Umberto Eco, Marco Santambrogio, and Patrizia Violi, editors, *Meaning and Mental Representations*, chapter Conceptual Semantics, pages 81–97. Indiana University Press, 1988.

Mark Johnson. *The Body in the Mind: The Bodily Basis of Meaning, Imagination, and Reason.* University of Chicago Press, 1987.

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.

Chris Kennedy and Beth Levin. Measure of change: The adjectival core of degree achievements. In L. McNally and C. Kennedy, editors, *Adjectives and Adverbs: Syntax, Semantics and Discourse*, pages 156–182. Oxford University Press, Oxford, UK, 2008.

Angelika Kratzer. Severing the external argument from its verb. In Johan Rooryck and Laurie Ann Zaring, editors, *Phrase Structure and the Lexicon*, pages 109 –137. Kluwer Academic Publishers, Dordrecht, 1996.

George Lakoff. Cognitive semantics. In Umberto Eco, Marco Santambrogio, and Patrizia Violi, editors, *Meaning and Mental Representations*, pages 119 – 154. Indiana University Press, 1988.

Beth Levin. *English verb classes and alternations: a preliminary investigation*. University of Chicago Press, 1993.

Tillmann Pross and Antje Roßdeutscher. Measuring out the relation between conceptual structures and truth-conditional semantics. Talk at Semantics and Philosophy in Europe 7, 2014a.

Tillmann Pross and Antje Roßdeutscher. Sublexical bridging of formal and conceptual semantics. Talk at Workshop Bridging Formal and Conceptual Semantics (BRIDGE-14), 2014b.

Tillmann Pross and Antje Roßdeutscher. The encoding of knowledge in linguistic structures. Talk at the Workshop Linguistic versus Non-Linguistic Knowledge, Tübingen, 2014c.

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.

G. Ramchand. *Verb Meaning and the Lexicon. A First Phase Syntax.* Cambridge University Press, 2008.

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.

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

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

Leonard Talmy. Force dynamics in language and cognition. *Cognitive Science*, 12:49 – 100, 1988.

Leonard Talmy. *Toward a cognitive semantics Vol.1*. MIT Press, 2000.

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. 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.