

# Formale Semantik

## 02. Referentielle Semantik

Roland Schäfer

Institut für Germanistische Sprachwissenschaft  
Friedrich-Schiller-Universität Jena

stets aktuelle Fassungen: <https://github.com/rsling/VL-Deutsche-Syntax>

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## Organization

- Chierchia & McConnell-Ginet, *Meaning and Grammar*
- Partee, ter Meulen & Wall, *Mathematical Methods in Linguistics*
- Blackburn, Bos & Striegnitz, *Learn Prolog now!*
- Blackburn & Bos, *Computational Semantics for Natural Language*

- Bucher, *Einführung in die angewandte Logik*
- Sag, Wasow & Bender, *Syntactic Theory*
- Dowty, *Tense, Time Adverbs, and Compositional Semantic Theory*
- Partee, *Noun Phrase Interpretation and Type-shifting Principles*
- Copestake, Flickinger & Sag *Minimal Recursion Semantics*

# The three sessions

- Formal Semantics, 90 min. on Wednesday
- PROLOG, 30 min. on Wednesday
- Tutorial, 90 min. on Friday
- Summer course (implementation), 1 week

# The first weeks: Preliminaries (subject to changes)

- Session 1 Introduction to Referential Semantics  
(CM chap. 1 & 2)
- Session 2 Set theory, ordering theory, statement  
logic  
(PMW chap. 1 - 6)
- Session 3 Predicate calculi (PMW chap. 7 & 8)

# The middle weeks: First steps (subject to changes)

- Session 4 Quantification and model theory  
(CM chap. 3)
- Session 5 Quantification in English (CM chap. 3)
- Session 6 Intensionality (CM chap. 5)
- Session 7 Tense, modals, complementizers  
(CM chap. 5)
- Session 8  $\lambda$  (CM chap. 7)



# The final weeks: Advanced topics (subject to changes)

Session 9	Word meaning (CM chap. 8)
Session 10	Generalized quantifiers (CM chap. 7)
Session 11	Type shifting (Partee)
Session 12	Underspecified scope (Copestake <i>et al.</i> )
Session 13	Backup session
Session 14	Final test on 2004-07-13

# What *meaning* could mean

- The meaning of an expression is the idea conveyed by it.
- ...is the mental image it creates.
- ...is what a speaker wants to achieve by uttering it.
- ...is the set of objects to which it refers (for example in the case of nouns).

# What the study of meaning could be

- The study of the intellectual concepts perceivable in the world.
- ...of how the brain processes expressions, relates it to (fields of) cognitive concepts.
- ...of how a discourse of planful and intelligent agents (humans) is structured.
- ...of the correspondences between expressions and objects; and of how expressions are combined to be used productively.

# What this class is about

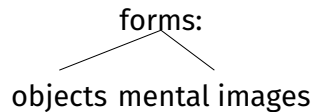
- Which objects do words refer to?
- What makes sentences true?
- How is the informational value of sentences related to their logical structure?
- How can sentences be unambiguously interpreted?

# What this class is **not** about

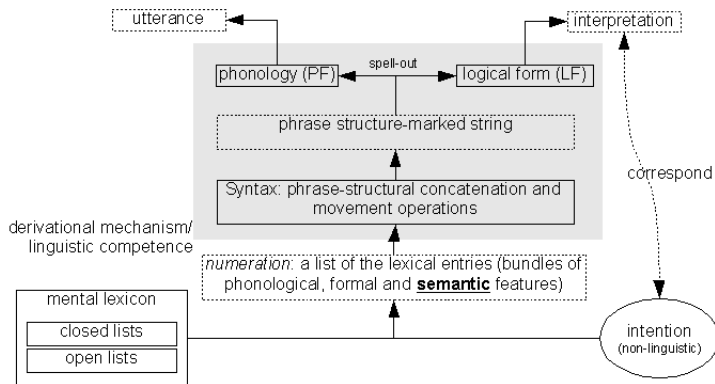
- what words mean,
- how the brain works with sentences,
- the structure of discourse (at least not much).

## Linguistic theories

# The theory of signs: a triangle



# Semantics in the Chomskian T-model





# LF is just the logical form

- No interpretation proper at LF.
- Movement transformations after the sentence has been uttered.
- At the LF level, sentences have a form compatible to their logic.
- Why? Syntax itself is often inadequate to express all alternatives of a sentence's logical representation.

A referential framework

# Some properties of language

- aboutness
- referential nature
- informative
- objectiveness (of content)
- But which linguistic elements refer to what?

an individual name  $\longrightarrow$  one object in the world

*Harald Schmidt*



a common noun → lots of objects

*soldier*



etc.

an adjective → lots of different objects of different kinds

*is human*



a sentence



a situation. a fact, ...

*A humming bird  
is hovering over  
a red flower.*



not at all  
(object type mismatch)



# Frege's Principle: Meaning is compositional

- *A humming bird* → one of many individuals
- *is hovering* → a property of that individual
- *over* → a relation between individuals
- *a red* → a property of another individual
- *flower* → the other one of many individuals
- *is hovering over a red flower* → a complex property.



# Recursion: infinite use of finite means

- Frege's principle is indispensable!
- *Harald Schmidt is human.*
- *Harald Schmidt is human and tall.*
- *Harald Schmidt is human and tall and male.*
- *Harald Schmidt is human and tall and male and not blue.*
- *Harald Schmidt is human and tall and male and not blue and grumpy in the morning...*

## Some fundamental semantic notions

# Basic semantics judgements

- entailment
- presupposition
- ambiguity
- synonymy

- A: *This is electronic.*
- B: *This is a presentation.*
- C follows logically: *This is an electronic presentation.*
- $A, B \vdash C$
- $A \not\vdash C$
- $B \not\vdash C$

# Entailment: pure logic, formally

- $D$ : *Harald Schmidt is human.*
- $E$  follows logically: *Something is human.*
- $D \vdash E$
- $D \wedge D$  follows logically: *Harald Schmidt is human and Harald Schmidt is human.*
- $D \vdash D \wedge D$

## Tests: X entails Y if...

- When X is true, Y is true.
- A situation described by Y is also described by X.
- The information given by Y is fully contained in the information given by X.
- One cannot say X is true and Y is false.

# Entailments?

- *Harald Schmidt is a talkmaster. → Harald Schmidt is human.*
- *Harald Schmidt is tall. → Someone is tall.*
- *Some humans are tall. → Harald Schmidt is tall.*
- *I have listened to Paul Kalkbrenner's new 12" on bpitchcontrol. → Paul Kalkbrenner has released a 12" on bpitchcontrol.*
- *After I had a Beck's, I installed RedHat on my PC. → I had a Beck's.*
- *After the bootloader had failed to boot RedHat on my PC, I had another Beck's. → RedHat has never booted on my PC.*
- *My flatmate likes Beck's. → My flatmate hates beer.*
- *Harald Schmidt cancelled his show. → Harald Schmidt's show was cancelled.*

# Presupposition: the background

- A: *Willy Brandt is the current chancellor of the FRG.*
- B: *If Willy Brandt is the current chancellor of the FRG, why doesn't he do something?*
- C: *Willy Brandt is not the current chancellor of the FRG.*
- A and B presuppose D: *Willy Brandt is alive.*, C doesn't.
- A, B, and C presuppose E: *There is a chancellor of the FRG.*
- Note:  $A \vdash D$ ,  $A \vdash E$
- But:  $B \not\vdash D$ ,  $B \not\vdash E$ ,  $C \not\vdash E$



# Presupposition: two tests

- Presuppositions are triggered by all sorts of sentences (incl. negations, modals, conditionals, etc.).
- Presuppositions can be negated while the sentence which presupposes them remains true. Entailments cannot be negated while keeping the entailing sentence true.

- *She saw the man with a telescope.*
- She [saw the man] with a telescope.
- She saw [the man with a telescope].

- *Everybody loves somebody.*
- Every person loves at least one other person.  
(Needn't be the same.)
- There is one person loved by everyone

- Lexical synonymy: *humming bird*  $\overset{lex}{\equiv}$  *colibri*
- Compositionally (**equivalence**): *Mulder met his abducted sister after he broke into the secret army base.*  $\equiv$  *Before meeting his abducted sister, Mulder broke into the secret army base.*
- $A \equiv B$  iff  $A \vdash B$  and  $B \vdash A$

From reference to sense

# Noun-like expressions and complex NPs

- I saw a man.
- I saw the green wobbly thing crawling near.
- I saw it.

- *The dark subatomic particles in the universe* have a total mass much larger than the visible subatomic particles.
- *Problems with referential semantic theories* don't concern *Rumplesteeze*.
- and of course, vagueness (e.g., Sorites Paradox)

# Problems with non-referential NPs

- *some guy*
- *not the faintest trace of blood*
- *any axiom of Zermelo-Fraenkel set theory*



We need a logic to explain for effects like:

	my humming bird's favorite flower	is red
⊢	some flower	is red

# Some content-synonymous simple expressions

- a: *colibri*
- b: *humming bird*
- c: *a brunette lady*
- d: *a brown-haired dame*
- e: *the primates*
- f: *the apes and humans*
- $a \stackrel{\text{lex}}{=} b, c \stackrel{\text{lex}}{=} d, e \stackrel{\text{lex}}{=} f$

# Some content-synonymous complex expressions

- A: *A colibri* is hovering over a red flower.
- B: *A humming bird* is hovering over a red flower.
- C: Lauren Bacall was *a brunette lady*
- D: Lauren Bacall was *a brown-haired dame*
- E: *Primates* are intelligent.
- F: *The apes and humans* are intelligent.
- $A \equiv B, C \equiv D, E \equiv F$

# Two axioms

- **Ax1** Two expressions (e.g., NPs, sentences) that are synonymous have the same reference.
- Formally:  $A \equiv B$  then  $\llbracket A \rrbracket = \llbracket B \rrbracket$
- Note:  $\llbracket A \rrbracket$  is applicable to simplex and complex expressions A; it just produces the reference of A.
- **Ax2** If we replace expression B within expression A with the synonymous expression C, then A does not change its reference.
- Formally: If  $\llbracket B \rrbracket = \llbracket C \rrbracket$  then  $\llbracket [A \ B] \rrbracket = \llbracket [A \ C] \rrbracket$

# One common property of sentences: the truth value

- A: *Lauren Bacall was a brunette lady.* (assumed to be true in the actual world)
- B: *My cat sleeps quietly.* (assumed to be true in the actual world)

# First conclusion

- $[\tau A]$  = *The truth value of 'Lauren Bacall was a brunette lady' is 1.*
- $[\tau B]$  = *The truth value of 'My cat sleeps quietly' is 1.*
- Such that  $A \equiv [\tau A]$  and  $B \equiv [\tau B]$ .  
(Check: Whenever A is true,  $[\tau A]$  is true and v.v.)
- So, by Ax1  $\llbracket A \rrbracket = \llbracket [\tau A] \rrbracket$   
and  $\llbracket B \rrbracket = \llbracket [\tau B] \rrbracket$

## Second conclusion

- Check the denotations of the contained NPs:  
 $\llbracket \textit{the truth value of A} \rrbracket = \llbracket \textit{the truth value of B} \rrbracket = 1$
- Such that by Ax2:  
 $\llbracket [\tau A] \rrbracket = \llbracket [\tau B] \rrbracket$
- Why? Exchanging the referentially identical NPs ‘the truth value of A’ and ‘the truth value of B’ in the otherwise identical sentences ‘\_ is 1’ forces us to conclude by Ax2 that also the whole sentences must have the same reference. Our book (CM) is a bit vague on that point.

$$\llbracket A \rrbracket = \llbracket \neg A \rrbracket = \llbracket \neg B \rrbracket = \llbracket B \rrbracket = 1$$

Sentences denote truth values.



- indirect encoding of 'richer' semantics (One must know the truth conditions of a sentence and the state of affairs to decide about the truth of a sentence.)
- a minimal common semantic property of sentences
- easily computable in a formal system (binary)
- their logic provides a basis for 'richer' semantics (cf. second half of class)

## Frege also thought, reference couldn't be all

Type	Reference	Sense
NP	individuals <i>Venus</i>	individual concepts
VP	sets <i>humming birds</i>	property concepts
S	1 or 0 <i>I like cats.</i>	thoughts

- *reference* = *extension* = what we're dealing with first
- *sense* = *intension* = what we will be dealing with later
- *proposition* = the intensions of sentences as informational content: The 'thought that S'.

We're talking in fragments: F1

# Decomposing compositionality and composing truth

- How are sentences compositionally built up?
- What do their parts denote?
- How does the denotation of the parts contribute to the whole.
- T-sentences:  $S$  of  $L$  is true in  $v$  iff  $p$ .
- $S$  a sentence,  $L$  a language,  $v$  a state of affairs,  $p$  a statement of the truth conditions.

# A phrase-structure grammar

- $S \rightarrow N VP$
- $S \rightarrow S \text{ conj } S$
- $S \rightarrow \text{neg } S$
- $VP \rightarrow V_i$
- $VP \rightarrow V_t N$

- $N \rightarrow$  *Herr Webelhuth, Frau Eckardt, the Turm-Mensa*
- $V_i \rightarrow$  *is relaxed, is creative, is stupid*
- $V_t \rightarrow$  *prefers*
- $conj \rightarrow$  *and, or*
- $neg \rightarrow$  *it is not the case that*

- $\llbracket \text{Herr Webelhuth} \rrbracket = \text{Herr Webelhuth}$
- $\llbracket \text{Frau Eckardt} \rrbracket = \text{Frau Eckardt}$
- $\llbracket \text{the Turm-Mensa} \rrbracket = \text{the Turm-Mensa}$
- $\llbracket \text{is relaxed} \rrbracket = \{x: x \text{ is relaxed}\}$
- $\llbracket \text{is creative} \rrbracket = \{x: x \text{ is creative}\}$
- $\llbracket \text{is stupid} \rrbracket = \{x: x \text{ is stupid}\}$
- $\llbracket \text{prefers} \rrbracket = \{\langle x, y \rangle: x \text{ prefers } y\}$



# Some words don't really 'denote', they act like functions

- $\llbracket \text{neg} \rrbracket = \begin{bmatrix} 1 \rightarrow 0 \\ 0 \rightarrow 1 \end{bmatrix}$
- $\llbracket \text{and} \rrbracket = \begin{bmatrix} \langle 1, 1 \rangle \rightarrow 1 \\ \langle 1, 0 \rangle \rightarrow 0 \\ \langle 0, 1 \rangle \rightarrow 0 \\ \langle 0, 0 \rangle \rightarrow 0 \end{bmatrix}$
- $\llbracket \text{or} \rrbracket = \begin{bmatrix} \langle 1, 1 \rangle \rightarrow 1 \\ \langle 1, 0 \rangle \rightarrow 1 \\ \langle 0, 1 \rangle \rightarrow 1 \\ \langle 0, 0 \rangle \rightarrow 0 \end{bmatrix}$

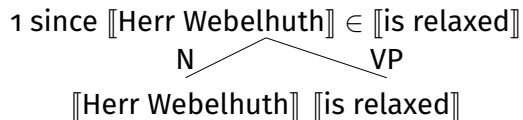
- $\llbracket [{}_S N VP] \rrbracket = 1$  iff  $\llbracket N \rrbracket \in \llbracket VP \rrbracket$ , else 0
- $\llbracket [{}_S S1 \text{ conj } S2] \rrbracket = \llbracket \text{conj} \rrbracket (\langle \llbracket S1 \rrbracket, \llbracket S2 \rrbracket \rangle)$
- $\llbracket [{}_S \text{ neg } S] \rrbracket = \llbracket \text{neg} \rrbracket (\llbracket S \rrbracket)$
- $\llbracket [{}_{VP} V_t N] \rrbracket = \{x: \langle x, \llbracket N \rrbracket \rangle \in \llbracket V_t \rrbracket\}$
- semantics for non-branching nodes: **pass-up**

## *Herr Webelhuth is relaxed.*

- Circumstances (Model): Herr Webelhuth is an element of the set of relaxed individuals.
- (1) The syntax is well-formed by  $S \rightarrow N VP$
- (2) for N:  $\llbracket \text{Herr Webelhuth} \rrbracket = \text{Herr Webelhuth}$
- (3) for VP:  $\llbracket \text{is relaxed} \rrbracket = \{x: x \text{ is relaxed}\}$
- (4) for S:  $\llbracket [S N VP] \rrbracket = 1$  iff  $\llbracket N \rrbracket \in \llbracket VP \rrbracket$ , else 0

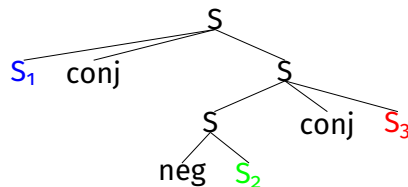
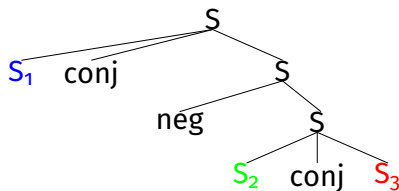
# A starting point for our computation

The tree:



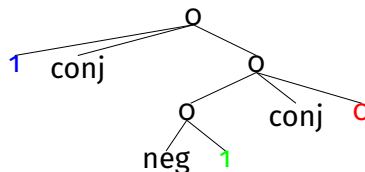
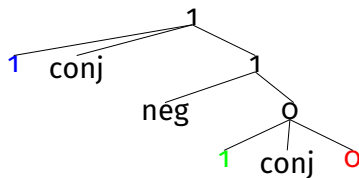
# We compute syntactic representations, not flat sentences

( $s_1$  Frau Eckardt is creative) and it is not the case that ( $s_2$  Herr Webehlhuth is relaxed)  
and ( $s_3$  Frau Eckardt prefers the Turm-Mensa).



# A starting point for our computation

Circumstances: Herr Webelhuth is relaxed, Frau Eckardt is creative, and Frau Eckardt does not prefer the Turm-Mensa:





## Kontakt

Prof. Dr. Roland Schäfer  
Institut für Germanistische Sprachwissenschaft  
Friedrich-Schiller-Universität Jena  
Fürstengraben 30  
07743 Jena

<https://rolandschaefer.net>  
[roland.schaefer@uni-jena.de](mailto:roland.schaefer@uni-jena.de)



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