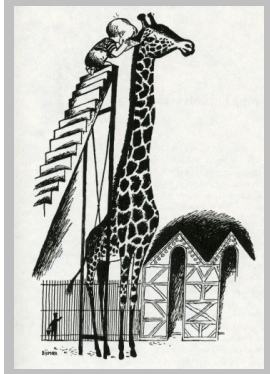
Between Logic and Common Sense

Or: Dikkertje Dap meets Dr. Halfbaked



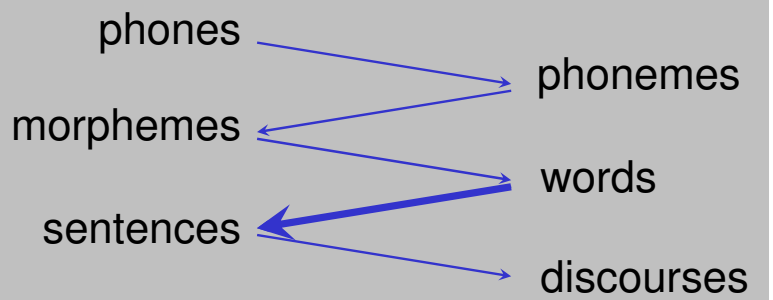
Yoad Winter

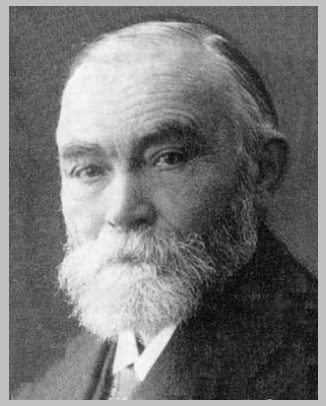
Technion &
Utrecht University

NICI, 20 May 2008

Main Puzzle:
How do words contribute to sentence understanding?

Typical situation in linguistics:





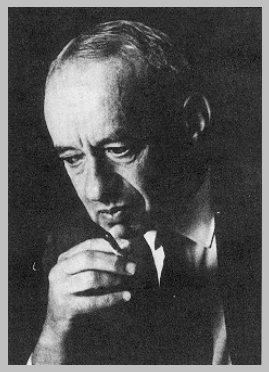
Gottlob Frege
(1848-1925)

Principle of Compositionality:

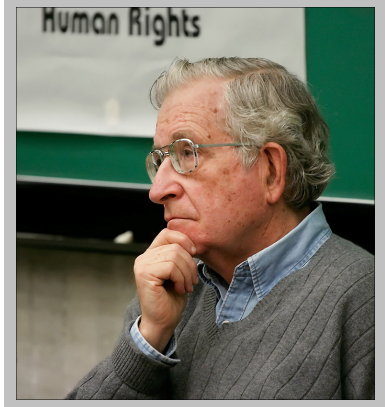
The meaning of a compound expression is a function of the meanings of its parts, and the ways they combine with each other.

Model-theoretic, Truth-conditional Semantics:

Meanings are defined relative to an algebraic *model*. The relations between meanings in the model are coupled to relations between *truth values* of sentences in the (artificial) language.



Alfred Tarski
(1902-1983)



Noam Chomsky (1928)

Universal Grammar:

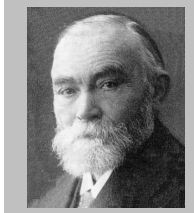
Central *structural* aspects of the human language faculty, and especially of language *acquisition*, are innate, and common to all human languages.

English as a formal language:

There is no fundamental difference between the techniques needed for treating the semantics of natural languages, and those needed for artificial-logical languages.

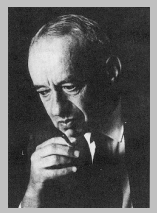
Richard Montague (1930-1971)

Logic and Language in the 20th Century



Gottlob Frege (1848-1925)

Form ↔ Meaning



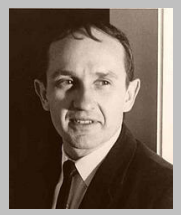
Alfred Tarski (1902-1983)

Current Tasks

Better relations with semantic performance

Better understanding of semantic resources themeselves

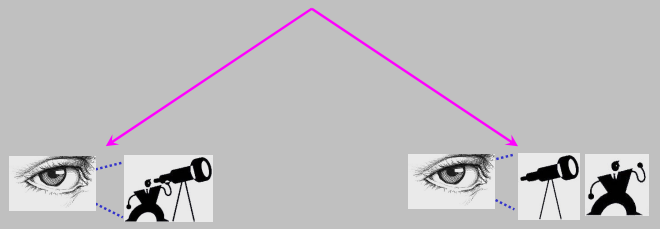
Noam Chomsky (1928)



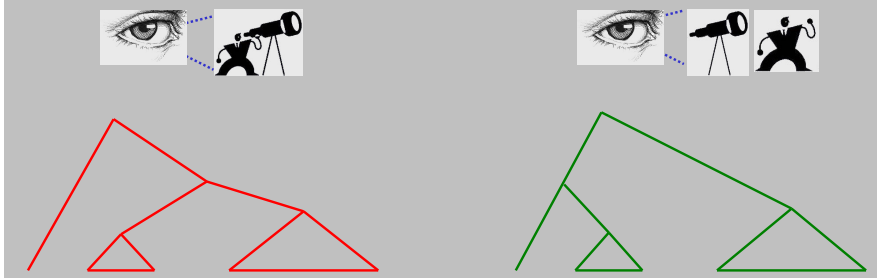
Richard Montague (1930-1971)

Ambiguous Expressions

I saw the man with the telescope



Syntactic-Semantic Ambiguity

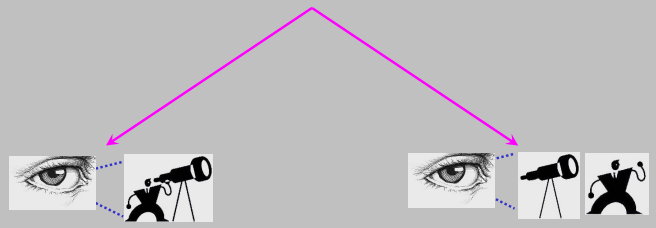


I saw the man with the telescope

The Challenge

So far so good for syntax-semantics mapping:

I saw the man with the telescope



- **But what are meanings themselves?**
- **Can the mapping between syntax and semantics be blind to the meanings it manipulates?**

Basic Distinction (e.g. Keenan)

Logical concepts = Tarksian operators:

$$\text{the}(N) = \begin{cases} x & \text{if } N=\{x\} \\ \text{undefined} & \text{otherwise} \end{cases}$$

Non-logical concepts

see; man; telescope **= ?**

General thesis:
Cognitive faculties of concept processing via prototypes may affect logical meanings as well as the composition process.

Areas: where semantics meets cognitive psychology

1. **Composition of simple *non-logical* concepts.** *stone lion*
2. **Composition of *non-logical* with *logical* concepts.** *follow each other*
3. **Modeling of logical relations between sentences in *Computational Semantics.***

Prototype Theory – reconstruction

Prototype of a concept: some structured collection of features that characterize preferred attributes for instances of the concept.

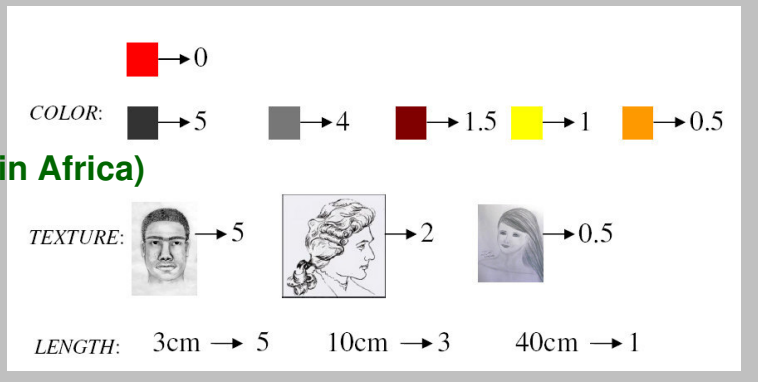
Categorization: prototypes are a vehicle for determining whether an object falls into a given conceptual category or not.

Prototype Theory - example

red:

1 3 5 3 1 ⟵ assuming a scale of 1-5

hair:
(say, in Africa)



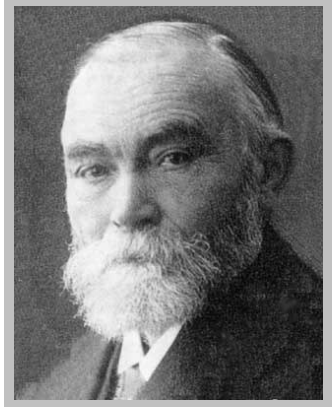
For Modeltheoretic Semantics, then:

Prototypes partake in determining the *extension* (referent, denotation) of non-logical expressions.

Note – this doesn't mean that extensions are necessarily graded.

It only means that if ▯ is in the extension of *red* in a given model, then also ▯ is.

Back to basics



Gottlob Frege (1848-1925)

On Sense and Reference

In terms of conceptual semantics:

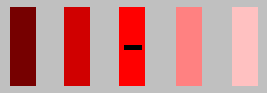
Sense = concept

Reference – determined by using concept for categorization

Sense as Prototype – Reference as Categorization

red – sense:

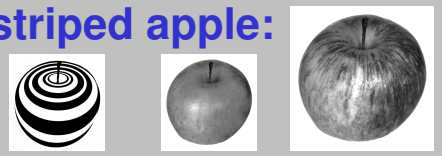
red – reference:



Osherson and Smith's Puzzle: Can Prototype Theory deal with concept composition?

red hair:

striped apple:



How do we create a complex prototype concept from two simpler prototypes?

Proposed answer: we don't.
Prototypes are only associated with **lexical** expressions - morphemes, words, idioms.

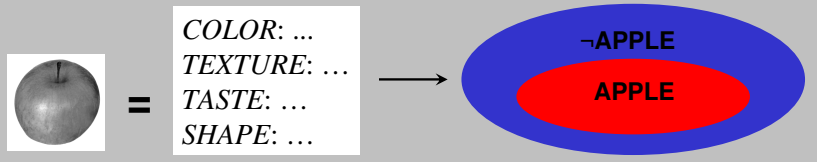
lexical *senses/intensions* = concepts
lexical *referents/extensions*, by way of categorization

and perhaps common collocations.

Concepts for **complex** expressions = senses, obtained by compositional interface between syntax and logical semantics.

A problem that is not a problem (1)

an apple that is not an apple (O&S)



Non-logical senses
= prototypes in lexical semantics.

Non-logical references
= use of prototypes for categorization

Compositional syntax and semantics:

APPLE ∩ ¬APPLE = Φ

A problem that is not a problem (2)

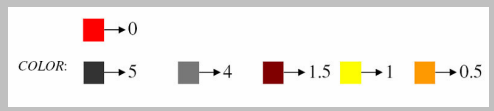
American city situated on the East Coast just a little south of Tennessee
(Fodor)

- Common collocations may perhaps have prototypes, based on experience with them.
- Idioms definitely should.
- But the less common a phrase is, the less likely it is to be connected to an independent prototype.

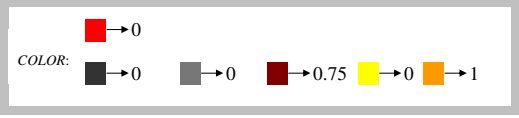
Locating the problem: modification

red:

hair:



red hair: (assume multiplication)



Head Primacy Principle

giant midget vs. ***midget giant***

Kamp and Partee:
"In a modifier-head structure, the head is interpreted relative to the context of the whole constituent, and the modifier is interpreted relative to the local context created from the former context by the interpretation of the head".

In simpler terms: in adjective-noun constructions, the adjective is "recalibrated" according to the noun, and not vice versa.

Implementing HPP (also Gardenfors)

Give the nominal scores higher factors than the adjectival scores.

midget:	0.5m→5	1.0m→4.5	1.5m→4	1.8m→1
		2.0m→0	3.0m→0	
giant:	0.5m→0	1.0m→0	1.5m→0.5	1.8m→2
		2.0m→4	3.0m→5	

$$an = a \cdot n^2/25$$

midget giant:	0.5m→0	1.0m→0	1.5m→1/25
	1.8m→4/25	2.0m→0	3.0m→0
giant midget:	0.5m→0	1.0m→0	1.5m→8/25
	1.8m→2/25	2.0m→0	3.0m→0

Possible extensions (also Gardenfors)

A later note: Analysis of the answers to some concerns raised by Osherson and Smith (1982) is beyond the scope of this presentation.

male nurse

stone lion

toy train

pet fish

etc.

Note: These only concern the "recalibration" of modifiers in nominal compounds; not necessarily a general theory of concept composition.

Problem: context dependence

Kamp:
My 2-year-old son built a tall snowman.

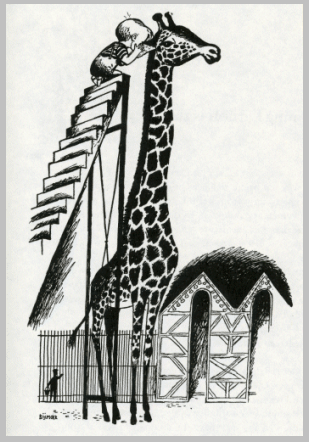
Question: What allows *tall* to be affected by the context here?

Answer (Kamp): The context-dependence of *tall.*
But also: the fact that *snowman* does not have a clear height standard – the modified noun has little effect on the adjective.

When the noun makes a difference

Dikkertje Dap climbed a tall giraffe.

Dikkertje Dap is the hero of a well-known Dutch poem by Annie M. G. Schmidt. After feeding a giraffe and talking to him, DD ends up sliding down the giraffe's neck, discovering how hard the ground of the Artis zoo in Amsterdam really is.



When context-dependence is weaker

Dr. Halfbaked had a complete idea.

In the 1970s Dr. Halfbaked was a main figure in an Israeli educational TV series for teaching English. This extraordinary scientist would often come up with improbable ideas. *Musical hamburgers* was one of my favorites.

Intermediate summary – prototypes in formal semantics

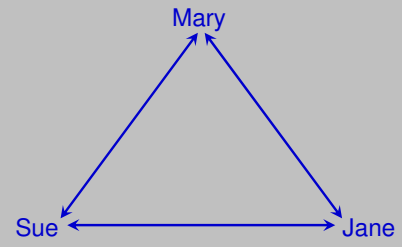
1 – May be needed for determining denotations of non-logical concepts.

2 – May affect the composition process with modifiers, but not necessarily in a general way.

3 – The way modifiers interact with prototypes and context requires attention, and experimentation.

More on HPP – relational prototypes and the logic of reciprocals

Mary, Sue and Jane know each other.

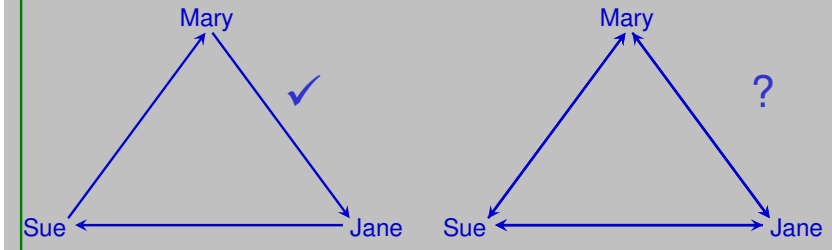


each other $\prec$ everybody…everybody-else

know $\prec$ know 1,2… people

Reciprocal and Relational Expressions – Dalrymple et al.

Mary, Sue and Jane are kicking each other.

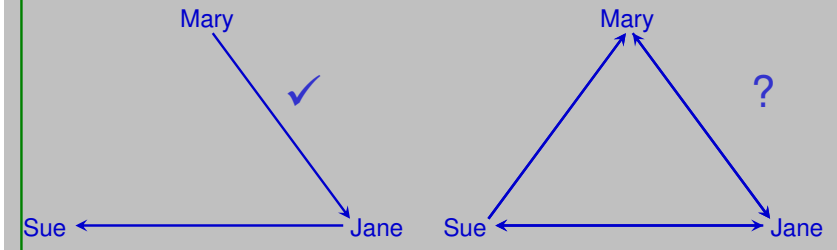


each other $\prec$ everybody…somebody-else

kick $\prec$ kick 1 person at a time

Reciprocal and Relational Expressions (cont.)

Mary, Sue and Jane are standing on each other.



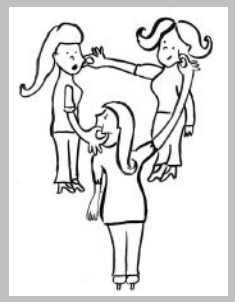
each other $\prec$ everybody… (R or is Red by) somebody-else

stand $\prec$ non-circular

Reciprocal and Relational Expressions (cont.)

Mary, Sue and Jane are pinching each other.

?



✓

each other $\prec$ everybody…somebody-else

pinch $\prec$ pinch 1 person at a time

Hypothesis: *Prototypes of relations affect the logic of reciprocals.*

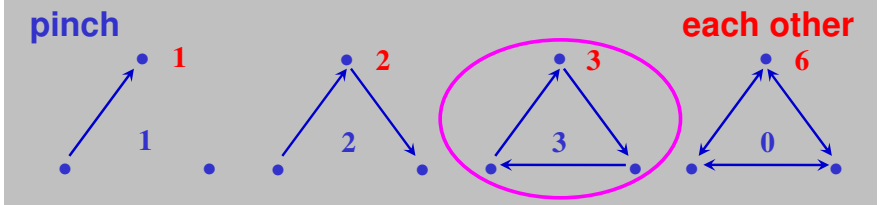
Common-sense:	Logic:	
We may know many people at the same time.	know each other	∀∀
We can only stand on in non-circular configurations.	stand on each other	...
We can (normally) only kick one person at the same time.	kick each other	∀∃
We are likely to pinch only one person at the same time.	pinch each other	∀∃

Thus, the logical aspects of language may be more sensitive to performance than what is sometimes believed.

HPP again

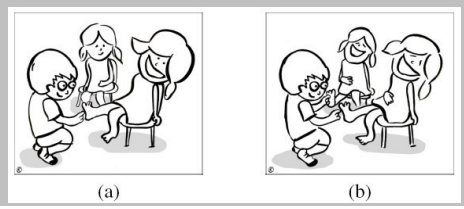
Adjective-Noun: Choose the maximally prototypical element(s) of the *noun* which respects preferences of the *adjective*.

Relation-Reciprocal: Choose the maximally prototypical element(s) of the *relation* that is consistent with the *reciprocal*.



Prototypes of Relations (1)

Work in progress with Nir Kerem and Naama Friedmann (Tel-Aviv)



Experiments run – prototypical binary relations

1. *Forced Choice*: Given two pictures like Figure 2a and Figure 2b, the subjects are asked to answer quickly:

   "Which situation describes better a tickling?"

2. *Sentence Completion*: Given two incomplete sentences like:

   The boy _____ the old man.
   The boy _____ the old men.

   Add the following verbs in the slots, one verb for each sentence: *hit, remembered.*

Prototypes of Relations (2)

Results so far (52 subjects):
Forced Choice:

1. Transitive verbs (in Hebrew – lexical TVs) that prefer a singular object: *stab, shake, hit, point at, wipe, comb, tickle, shoot at, touch, put make up on, clean, scratch, paint*.
2. Transitive verbs that prefer a plural object: *make a speech to, take a picture of, draw*.

Sentence Completion: Singular-Plural object pairs – *catch-know, tickle-make laugh, scratch-forget, push-hate, stub-take away, stub-meet, hug-remember, hug-make thrilled, lean on-control,*

Summary

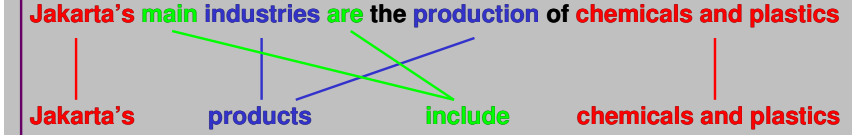
1 – Relational expressions may have prototypes.

2 – These may affect the composition process with reciprocals.

3 – According to the Head Primary Principle of Kamp and Partee.

Application in Computational Semantics: Acquiring word-sentence meaning interactions

Textual Entailment (Dagan et al.):



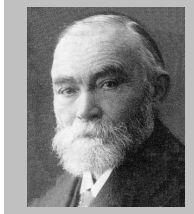
Research Question:

How can machine learning techniques acquire interactions between lexical relations and sentential relations like entailment?

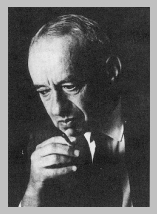
Answer Requires:

1. A better understanding of the relations between the semantics of lexical concepts and compositional processes in logical semantics.
2. A way to obtain large-scale automatic acquisition of logically relevant concepts from available resources.

Logic, Language and Cognition in the 21st Century



Gottlob Frege
(1848-1925)



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Common Sense

Form ↔ Meaning

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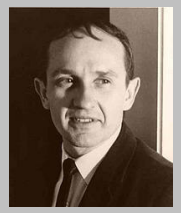
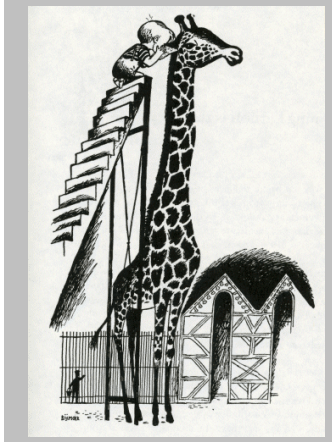
(1928)



Richard Montague
(1930-1971)

A tall order, to be sure!



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