EBERHARD KARLS
UNIVERSITÄT
TÜBINGEN

Faculty of Philosophy
General Linguistics

Semantics & Pragmatics SoSe 2022

Lecture 14: Discourse Representation Theory I

23/06/2022, Christian Bentz

Overview

Section 1: Recap of Lecture 13

Historical Note

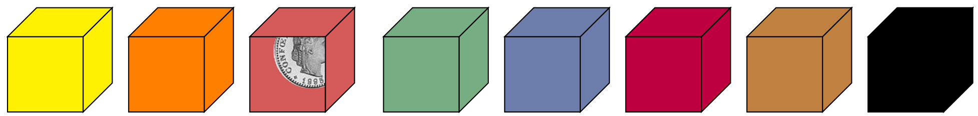
"The modern usage of the term **pragmatics** is attributable to the philosopher Charles Morris (1938), who was concerned to outline (after Locke and Peirce) the general shape of a science of signs, or **semiotics** (or semiotic as Morris preferred). Within semiotics, Morris distinguished three distinct branches of inquiry [...]"

1. **syntactics (or syntax)**: the study of "the formal relation of signs to one another",
2. **semantics**: the study of "the relations of signs to the objects to which the signs are applicable" (their designata),
3. **pragmatics**: the study of "the relation of signs to interpreters".

Levinson (1983), p. 1, citing Morris (1938).

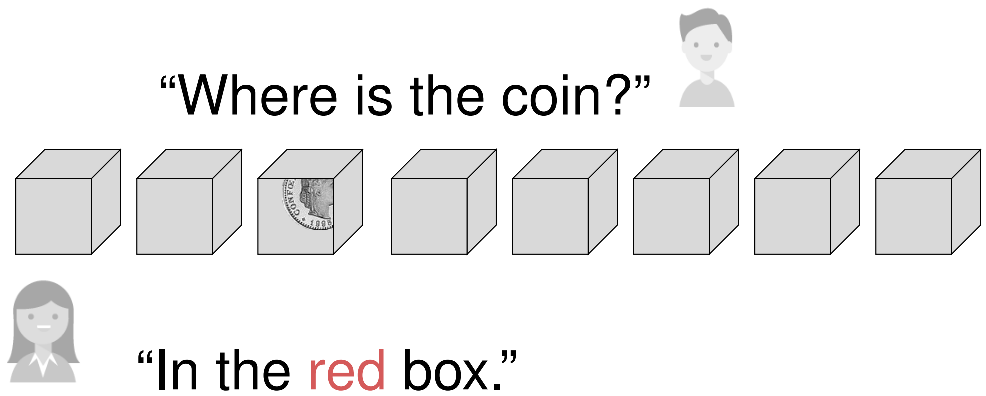
Remember the Box Game

"Where is the coin?"

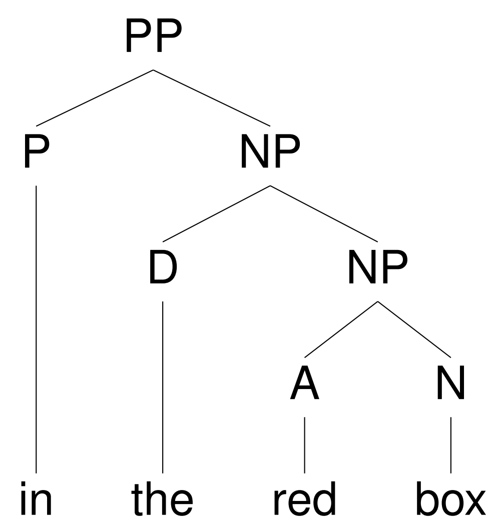


"In the red box."

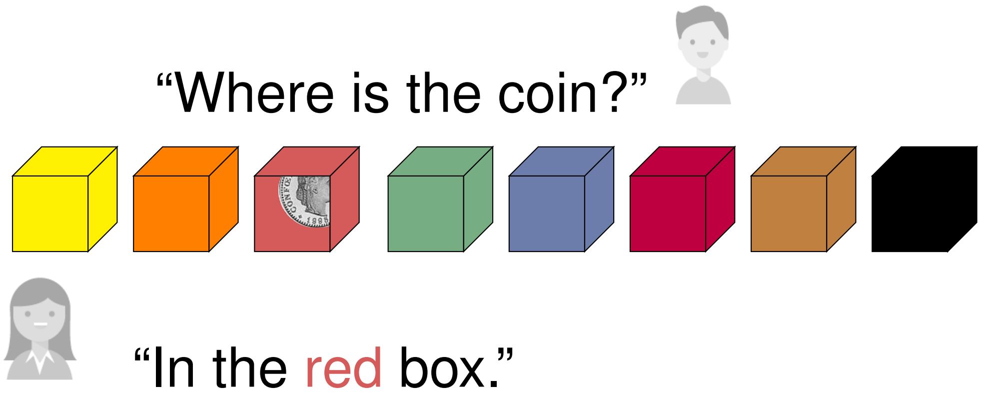
Syntax in the Box Game



In a strict definition of **syntax**, we are purely interested in how the signs (e.g. words) relate to one another, i.e. how they are **arranged with reference to one another**. How they relate to the objects and how they are interpreted by the speaker and hearer is secondary – though it is still considered relevant how they are processed in human brains.



Semantics in the Box Game



In **semantics**, we are interested **how signs map to the objects** they (are supposed to) refer to. In formal semantics, this is modelled via translation into a logical language, and a definition of a model world according to which the truth of statements can be evaluated. Note that this is **independent of the interpretations of the speaker and hearer** based on contextual considerations.

First Order Predicate Logic

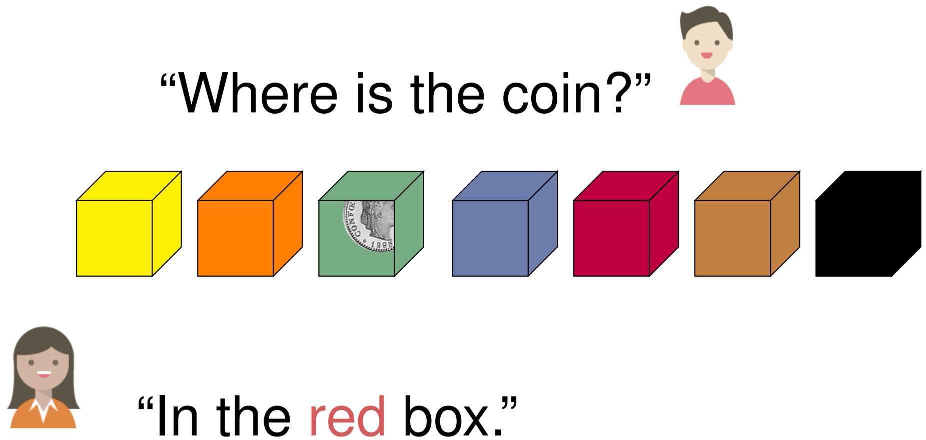
"The coin is in the red box."

$\phi = \text{Icb} \wedge \text{Rb}$

Ixy: x is in y
Rx: x is red
c: the coin
b: the box

Valuation by interpretation function: I(ϕ) = 1

Pragmatics in the Box Game



Pragmatics goes beyond the pure connection of signs (syntax), the truth-conditional (or other type of) mapping of signs to objects (semantics), by taking into account further **contextual information** that speaker and hearer might harness when formulating and interpreting utterances. This is especially important when a “standard interpretation” of the utterance fails.

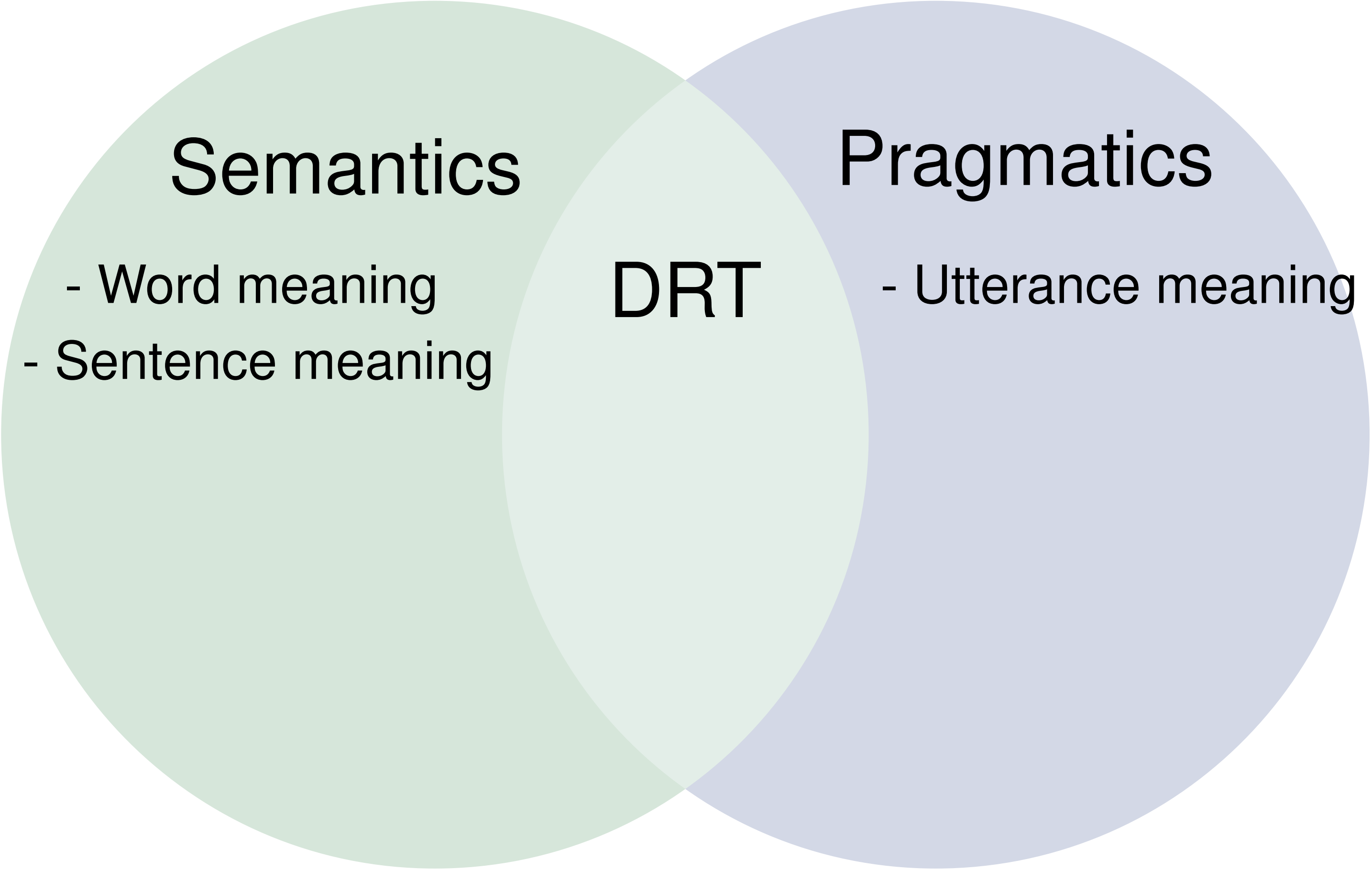
Possible Definitions of Pragmatics

- Anomaly Definition
- Functional Definition
- Context Definition
- Grammaticalization Definition
- Truth-Conditional Definition
- Inter-Relation Definition
- Appropriatness/Felicity Definition
- List Definition

Inter-Relation Definition

"[...] the term *pragmatics* covers both **context-dependent aspects of language structure** and **principles of language usage** and understanding that have nothing or little to do with linguistic structure [...] pragmaticists are specifically interested in the **inter-relation of language structure and principles of language usage**."
Levinson (1983), p. 9.

"Pragmatics is the study of the **relations between language and context** that are basic to an account of language understanding."
Levinson (1983), p. 21.



DRT: Discourse Representation Theory

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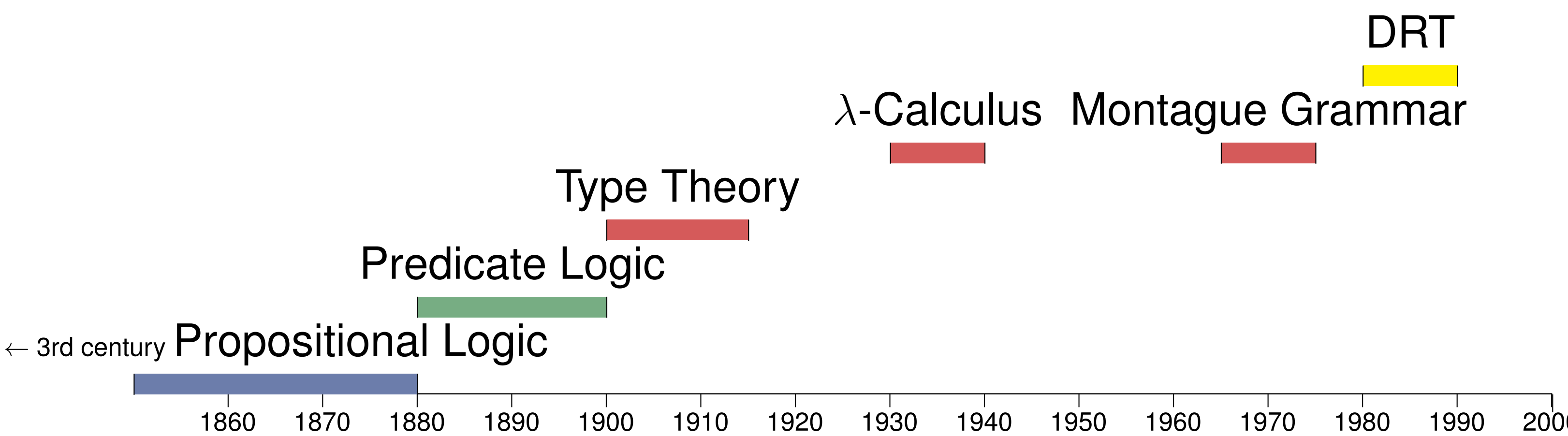
Section 2: DRT Introduction

Historical Background

"In the early 1980s, **Discourse Representation Theory (DRT)** was introduced by Hans Kamp as a theoretical framework for dealing with issues in the semantics and pragmatics of anaphora and tense (Kamp 1981); a very similar theory was developed independently by Irene Heim (1982)."

Geurts & Beaver (2007), p. 1.



Indefinites: A semanticist's riddle

Irene R. Heim

Barbara Partee

One standard view among logicians is that indefinite noun phrases like 'a tall man' are not referring expressions, but quantifier phrases, like 'every man', 'no man', and 'most men'. Yet in many respects, indefinite noun phrases seem to function in ordinary language much like definite noun phrases or proper names, particularly with respect to the use of pronouns in discourse. This may be simply a matter of sorting out semantics from pragmatics [...]

Heim (1982), p. 4 citing Barbara Partee.

(1) **A dog** came in. **It** lay down under the table.

Indefinites: A semanticist's riddle

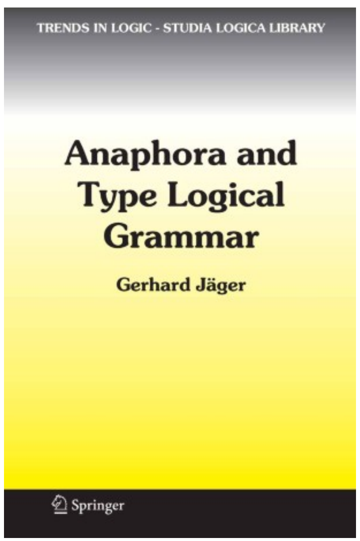
Hans Kamp

The choice of this fragment is motivated by two central concerns: (a) to study the anaphoric behaviour of personal pronouns; and (b) to formulate a plausible account of the truth conditions of the so-called "donkey-sentences" [...]

Kamp (1981), p. 2-3.

(2) If Pedro owns **a donkey** he beats **it**.

Anaphora in Typed Logic



Gerhard Jäger

This book discusses how Type Logical Grammar can be modified in such a way that a systematic treatment of anaphora phenomena becomes possible without giving up the general architecture of this framework.

Jäger (2005), p. ix.

(3) John$_i$ invented a problem that he$_i$ could not solve.

(4) [Every student]$_i$ invented a problem that he$_i$ could not solve.

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Differences to Classical Formal Semantics

Some **differences** to classical formal semantic frameworks, e.g. standard predicate logic and type-theoretic logic, include:

- DRT deals with interpretations **not only of individual sentences**, but of **discourse structures**.

  $\rightarrow$ **Discourse** Representation Theory

- It is a **mentalist and representationalist** theory of interpretation of natural language structures, i.e. it aims to explicitely represent in its formulations what is represented in the human mind when interpreting natural language.

  $\rightarrow$ Discourse **Representation** Theory

Geurts & Beaver (2007), p. 1.

Similarities to Classical Formal Semantics

Some **similarities** to classical formal semantic frameworks, e.g. standard predicate logic and type-theoretic logic, include:

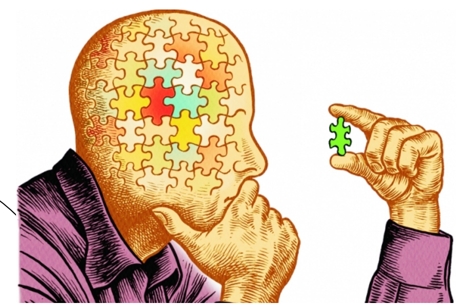
- Usage of logical operators and variables (e.g. $\neg$, $\rightarrow$, $\forall$, x, y, etc.).
- It is based on a model-theoretic framework, e.g. using valuation/verifying functions, for assigning truth values to expressions.

Geurts & Beaver (2007), p. 1.

Discourse Representation Structures

“DRT’s main (and most controversial) innovation [...] is that it introduced a level of mental representations, **called discourse representation structures (DRSs)**. The basic idea [...] is that a hearer builds up a mental representation of the discourse as it unfolds, and that every incoming sentence prompts additions to that representation.”

Geurts & Beaver (2007), p. 2.



Bambi$_i$ gave Maya$_j$ flowers$_k$. She$_j$ thanked her$_i$ for them$_k$.

Anaphora Resolution

The problem of how hearers are able to **“resolve” anaphora**, e.g. to know which **referent (antecedent)** of the discourse a **pronoun (consequent)** is referring back to, has received attention from both syntacticians and semanticists over the course of centuries. It has resisted straightforward explanations.

If Bambi$_i$ gives Maya$_j$ flowers$_k$ she$_j$ will like them$_k$.

Note: While anaphora resolution across sentences might be considered outside the scope of classical syntax and semantics – as these theories mostly deal with single sentences – the same problems also occur within sentences.

Historical Aside: Donkey Pronouns

There is a **set of sentences** which have been used since (at least) medieval times to illustrate the various issues with anaphora resolution. Since these deal with donkeys, their owners, and the pronouns referring back to them, they are often talked and written about as “donkey pronouns”.

(5) Omne homo habens asinum videt illum.
‘Every man who has a donkey sees it.’

Wikipedia, citing Walter Burley (1328), *De puritate artis logicae tractatus longior.*

Note: Following Geurts & Beaver (2007) we use underlining here to indicate the antecedent (e.g. *asinum*) and consequent (e.g. *illum*) of the anaphora.

Anaphora in a Formal Framework

Generally speaking there are three possibilities of how to deal with anaphora resolution in a formal framework (according to Geurts & Beaver 2007):

- Anaphora as **co-reference**
- Anaphora as **binding**
- Anaphora as neither **co-reference nor binding**

Anaphora as Co-Reference

In some cases, anaphora links are established between **referring expressions** (e.g. definite noun phrases, proper names) and the pronouns referring back to those. In these cases, the antecedent and consequent **co-refer** to the entitiy/individual in the real world.

Geurts & Beaver (2007), p. 3.

(6) John likes his donkey.
Predicate Logic: Ojd ∧ Ljd; Oxy: x owns y, Lxy: x likes y.

(7) Maya likes the flowers that were given to her.

(8) Mary entered the place. She stunned everyone.

(9) The huge mountain was ahead of them. It looked unsurmountable.

Anaphora as Binding

In other cases, however, the relation between antecedent and consequent is rather that of **binding**. Namely, the former binds the latter in the *logical sense of the word*, i.e. as a quantifier binds a variable in standard predicate logic.

Geurts & Beaver (2007), p. 3.

(10) No farmer likes his donkey.
$\neg\exists x\exists y((Fx \wedge Dy \wedge Oxy) \rightarrow Lxy)$

Note: No farmer does not refer to an entity in the world, hence, its relationship with **his** cannot be one of co-reference. We will here use standard predicate logic notation as established in the respective lectures based on Gamut (1991), Volume 1. The translation key is: Fx: x is a farmer, Dy: y is a donkey, Oxy: x owns y, Lxy: x likes y.

A Third Case: Neither Co-Reference nor Binding?

"In large part, the motivation for developing dynamic theories of interpretation, beginning with DRT, was the realization that the **dichotomy between referential and bound-variable (occurrences of) pronouns** is less natural than one might think – less natural in the sense that **some pronouns don't fit comfortably in either category**."
Geurts & Beaver (2007), p. 4.

(11) John owns a donkey. It is grey.

What is the relationship between the indefinite noun phrase *a donkey* and the pronoun *it*?

Example: Indefinite Noun Phrases and Pronouns

The relationship between a **pronoun** and an **indefinite noun phrase** is unlikely one of co-reference.

Geurts & Beaver (2007), p. 4.

(12) John does not own Jumbo. Rather, he is owned by [...]

(13) John does not own the donkey. Rather, it is owned by [...]

(14) John does not own a donkey. Rather, #it is owned by [...]

Note: If the relationship was that of co-reference to an entity, then this should also work with negation (as it does for definite noun phrases or proper nouns), but it does not. Generally speaking, indefinite noun phrases are not considered referring expressions according to standard logic.

Example: Indefinite Noun Phrases and Pronouns

Neither is there a straightforward, principled way to represent **indefinite noun phrases as quantifiers** and pronouns as variables bound by them in standard logic.

Geurts & Beaver (2007), p. 5.

(15) John owns a donkey. It is grey.
$\exists x(Dx \wedge Gx \wedge Ojx)$

(16) If John owns a donkey, he likes it.
$\forall x((Dx \wedge Ojx) \rightarrow Ljx)$

Note: In the standard predicate logic translation of the first example, we just ignore the sentence boundary (which is the reason, however, for why a pronoun is introduced in the natural language sentence). Also, while in the first example we use the existential quantifier (which seems to meet our intuition of the meaning of an indefinite phrase), in the second example we need to use the universal quantifier. Hence, the indefinite now (suprisingly) has universal force.

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Section 3: Basic DRT

Discourse Representation Structures

A DRS consists of **two major parts**:

1. a set of **discourse referents**,
2. a set of so-called **DRS-conditions** which capture the information about referents that has accummulated over the discourse.

(17) John chased Jumbo.
[x, y: John(x), Jumbo(y), chased(x,y)]

(18) John chased a donkey.
[x, y: John(x), donkey(y), chased(x,y)]

(19) A farmer chased the donkey.
[x, y: farmer(x), donkey(y), chased(x,y)]

Note: The colon ‘:’ delimits the set of discourse referents from the set of discourse conditions.

Discourse Referents

Discourse referents are a concept similar to the *domain of discourse* in standard logic. However, note that there are *no constants* here, all entities are represented with *variables* (x, y, etc.). The variables then have to be assigned to proper names, definite noun phrases, indefinite noun phrases via discourse conditions.

(20) John chased Jumbo.
[x, y: John(x), Jumbo(y), chased(x,y)]

(21) John chased a donkey.
[x, y: John(x), donkey(y), chased(x,y)]

(22) A farmer chased the donkey.
[x, y: farmer(x), donkey(y), chased(x,y)]

Discourse Conditions

Discourse Conditions are then similar to *predicates* in standard logic (but including equations like $x = y$).

(23) John chased Jumbo.
[x, y: John(x), Jumbo(y), chased(x,y)]

(24) John chased a donkey.
[x, y: John(x), donkey(y), chased(x,y)]

(25) A farmer chased the donkey.
[x, y: farmer(x), donkey(y), chased(x,y)]

Merging Operation

Beyond single sentences (or parts of sentences) discourse structures can be built also for consecutive sentences by **merging** their DRSs using the **⊕-operator**, which is defined as their pointwise union from a set-theoretic perspective.

(26) A farmer chased a donkey.
[x, y: farmer(x), donkey(y), chased(x,y)]

(27) He caught it.
[$\underline{v}$, $\underline{w}$: caught(v, w)]

Geurts & Beaver (2007), p. 7.

Note: The discourse referents of the second sentence are here underlined to indicate that they are in need of antecedents. Geurts & Beaver (2007) do not further explain according to which rules exactly the underlined discourse referents (v, w) are matched with the discourse referents in the former DRS (x, y). In English, this could be done, for instance, via grammatical gender and/or word order.

Example

[x, y: farmer(x), donkey(y), chased(x,y)] $\oplus$ [$\underline{v}$, $\underline{w}$: caught(v, w)] $=$

[x, y, $\underline{v}$, $\underline{w}$: farmer(x), donkey(y), chased(x,y), caught(v, w)] $=$

[x, y, v, w: v=x, w=y, farmer(x), donkey(y), chased(x,y), caught(v,w)] $=$

[x, y: farmer(x), donkey(y), chased(x,y), caught(x,y)]

- The first line is just the original DRSs connected with the $\oplus$-operator.
- In the the second line, all discourse referents which are not already represented in the former DRS are added to the set of discourse referents, and likewise for the discourse conditions (pointwise union).
- In the third line, discourse conditions are added (equations) to model the mapping of antecedents to consequents.
- In the last line, these are then "resolved", i.e. replaced by the original discourse referents x and y.

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Section 4: Complex DRS Conditions

Complex DRS Conditions: Negation

The above example deals with **simple, i.e. non-embedded DRS conditions**. However, there are various natural language scenarios that require more **complex DRS conditions**, i.e. **embedded** DRS conditions. One such example is **negation**.

(28) John doesn't own a donkey.
$[_1$ x: John(x), $\neg[_2$ y: donkey(y), owns(x,y)]]

(29) It is grey.
[$\underline{z}$: grey(z)]

Geurts & Beaver (2007), p. 7-8.

Note: The negation here scopes over *owns a donkey*, not over *John*. This scope is reflected in the embedded DRS.

Merging Operation Example: Negation

$[_1$ x: John(x), $\neg[_2$ y: donkey(y), owns(x,y)]] $\oplus$ [$\underline{z}$: grey(z)] $=$

$[_1$ x, $\underline{\mathbf{z}}$: John(x), $\neg[_2$ y: donkey(y), owns(x,y)], **grey(z)**]

- The first line is just the original DRSs connected with the $\oplus$-operator.
- In the second line, we add the variable $\underline{z}$ and the discourse condition grey(z) to the **outermost** set of discourse referents (i.e. in $[_1 \ldots]$).
- Importantly, $\underline{z}$ **does not have access** to y, since the DRS in which $\underline{z}$ is introduced, **does not have access** to the DRS where y is introduced. Hence, z cannot be equated to y. This correctly models the fact that *it* cannot refer back to *a donkey* in this negated sentence. See the next slide for an informal definition of **accessibility**.

Accessibility: Informal Definition

Every DRS is **accessible** to all and only those DRSs **whose number (representing the level of embedding) is bigger or equal to**[1] its own (so every DRS is accessible to itself).

(30) [x, y, v, w: farmer(x), donkey(y), chased(x,y), caught(v, w)]

(31) $[_1$ x, z: John(x), $\neg[_2$ y: donkey(y), owns(x,y)], grey(z)]

Note: The examples are repeated from above. In the first example, all variables have access to all other variables, since they are all part of the same DRS. In the second example, on the other hand, the DRS in $[_1 \ldots]$ is accessible to the DRS in $[_2 \ldots]$, but not the other way around.

[1] There seems to be an error in the formulation by Geurts & Beaver (2007), p. 13. They write "[...] every DRS is accessible to all and only those DRSs whose number *does not exceed* its own." But this seems just the inverse of how accessibility is defined and used in the rest of the paper. Also, the statement does not hold for DRSs connected by logical "or".

Complex DRS Conditions: Conditionals

Similar to negation, **conditionals (material implication)** also gives rise to complex, i.e. embedded DRS structures.

(32) If John owns a donkey, he likes it.
$[_1$: $[_2$ x, y: John(x), donkey(y), owns(x,y)] $\rightarrow$ $[_3$ $\underline{v}$, $\underline{w}$: likes(v,w)]]

Note: Geurts & Beaver (2007), p. 8 put *John(x)* outside of $[_2 \ldots]$. However, it is unclear why *John(x)* would not belong to the antecedent of the conditional. In fact, Kamp (2016), p. 13 puts it inside $[_2 \ldots]$. We follow Kamp (2016) here. As to accessibility: The discourse referents x and y are accessible to v and w as before in the case of the conditional.

Anaphora Resolution: Conditional

$[_1\!: [_2$ x, y: John(x), donkey(y), owns(x,y)] $\rightarrow$ $[_3$ $\underline{\text{v}}$, $\underline{\text{w}}$: likes(v,w)]] $=$

$[_1\!: [_2$ x, y, v, w: v=x, w=y, John(x) donkey(y), owns(x,y)] $\rightarrow$ $[_3$: likes(v,w)]] $=$

$[_1\!: [_2$ x, y: John(x), donkey(y), owns(x,y)] $\rightarrow$ $[_3$: likes(x,y)]]

- The first line represents the original DRS structure.
- The second line now adds the matching between variables. x and y are accessible to $[_2 \ldots]$ and $[_3 \ldots]$, hence, they are accessible to v, and w, which allows for v=x, and w=y.
- Line three then represents the DRS structure with fully resolved anaphora.

Complex DRS Conditions: Quantification

Quantification also involves complex DRS conditions. Namely, a quantifier Q over a discourse referent x, i.e. Qx, connects two DRSs, i.e. DRS and DRS′, such that we have DRS(Qx)DRS′. In this respect, **conditionals and quantifiers give rise to essentially the same structure**.

Geurts & Beaver (2007), p. 9.

(33) Every farmer who owns a donkey, likes it.

(34) If a farmer owns a donkey, he likes it.

$[_1$: $[_2$ x,y: farmer(x), donkey(y), owns(x,y)] $(\forall x)$ $[_3$ $\underline{v}$, $\underline{w}$: likes(v,w)]]
$[_1$: $[_2$ x,y: farmer(x), donkey(y), owns(x,y)] $\rightarrow$ $[_3$ $\underline{v}$, $\underline{w}$: likes(v,w)]]

Note: It is (implicitely) assumed here that in the first example we also have a pronoun as the subject of the consequent statements (*likes it*), while it is not explicitly realized here.

Anaphora Resolution: Quantification

$[_1$: $[_2$ x,y: farmer(x), donkey(y), owns(x,y)] ($\forall$x) $[_3$ $\underline{v}$, $\underline{w}$: likes(v,w)]] =

$[_1$: $[_2$ x, y, v, w: v=x, w=y, farmer(x), donkey(y), owns(x,y)] ($\forall$x) $[_3$: likes(v,w)]] =

$[_1$: $[_2$ x, y: farmer(x), donkey(y), owns(x,y)] ($\forall$x) $[_3$: likes(x,y)]]

- The first line represents the original DRS structure.
- In the second line, the discourse referents v and w, as well as the conditions v=x and w=y are added to the DRS in $[_2 \ldots]$. This is possible since x and y are accessible to v and w in $[_3 \ldots]$.
- Line three then represents the DRS structure with fully resolved anaphora.

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Summary

Summary

- **Discourse Representation Theory** was introduced in the early 1980s to account for the dynamic nature of discourse structure beyond individual sentences.
- It uses some concepts known from traditional formal semantics accounts, e.g. **quantification**, **conditionals**, **model-theoretic tools**.
- It differs from former accounts by emphasizing the relevance of **mental representations**, and **concatenation of sentences**.

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Thank You.

Contact:

Faculty of Philosophy
General Linguistics
Dr. Christian Bentz
SFS Wilhelmstraße 19-23, Room 1.24
chris@christianbentz.de
Office hours:
During term: Wednesdays 10-11am
Out of term: arrange via e-mail