



# Structured Nominal and Modal Reference

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# 1. Introduction

"Consider a device designed to read a TEXT in some natural language, interpret it and store the content in some manner, say, for the purpose of being able to answer questions about it.

To accomplish this task, the machine will have to fulfill at least the following basic requirement.

It has to be able to build a FILE that consists of RECORDS OF ALL THE INDIVIDUALS, that is, events, objects, etc., mentioned in the text and, for each individual, record whatever is said about it."

(Karttunen 1976: 364)



# 1. Introduction

"Consider a device designed to read a TEXT..."

... i.e. a **discourse**, not a sentence in isolation.

"As a rule discourse meanings are more than plain conjunctions of sentence meanings. And this 'more' is often the effect of interpretation principles that are an integral part of linguistic knowledge, and thus legitimate objects of linguistic study" (Kamp 2001: 57)



# 1. Introduction

"Consider a device designed to read a TEXT..."

The **information** that a sentence conveys is

NOT JUST: "information to the effect that the sentence is true, that the world is such as to meet the truth-conditions of the sentence." (Hintikka 1969: 146)

BUT ALSO: information about how to **change** the **information** / **context** relative to which subsequent expressions are interpreted.



# 1. Introduction

"Consider a device designed to read a TEXT..."

The problem of discourse interpretation

shifts our perspective on the **meaning** of natural language expressions

**from:** a static **truth-conditional** theory of meaning

**to:** a dynamic theory of meaning as **information update.**



# 1. Introduction

"[...] the machine [...] has to be able to build a **FILE** that consists of **RECORDS OF ALL THE INDIVIDUALS ...**"

We need a notion of **discourse reference**

that mediates between linguistic expressions and their reference (in the classical, truth-conditional sense).

The text interpreter incrementally builds a **file**, which encodes the current **information state** of the interpreter, i.e. the **context of interpretation** (updated in discourse).



# 1. Introduction

**"[...] the machine [...] has to be able to build a FILE that consists of RECORDS OF ALL THE INDIVIDUALS ..."**

The **information state** should be able:

- to encode when a novel individual is mentioned in discourse
- to store it along with its characterization for future reference

(Karttunen 1976)



# 1. Introduction

The shift from **truth-conditions** to **information update** and from **reference** to **discourse reference**

enables us to account for **cross-sentential** anaphora:

1. a.  $A^u$  man came in.      b.  $He_u$  sat down.

but also for **intra-sentential** donkey anaphora:

2. Every farmer who owns a $^u$  donkey beats it $_u$ .

[**Intra-sentential** anaphoric phenomena support the idea that information update and discourse reference are in fact **semantic** and not pragmatic notions]



# 1. Introduction

The main proposal of the dissertation:

Both **nominal** and **modal** expressions introduce

possibly non-singleton **sets of objects**

(individuals and possible worlds respectively)

and

these sets are **semantically correlated** in discourse.



# 1. Introduction

**The main proposal of the dissertation (ctd.):**

Discourse reference involves **two equally important components** with essentially **the same interpretive dynamics**:

- o reference to **values**, i.e. the sets of objects;
- o reference to **structure**, i.e. the correlation / dependency between such sets, which is introduced and incrementally elaborated upon in discourse.

Hence: **Structured Nominal and Modal Reference**



# 1. Introduction

**The main proposal of the dissertation (ctd.):**

**Structured discourse reference** enables us to account for sentences that contain **multiple** instances of singular donkey anaphora that are semantically **correlated**:

3. Every person who buys a  $u_2$  book on amazon.com and has a  $u_3$  credit card uses it $_{u_3}$  to pay for it $_{u_2}$ .
4. Every boy who bought a  $u_2$  Christmas gift for a  $u_3$  girl in his class asked her $_{u_3}$  deskmate to wrap it $_{u_2}$ .



# 1. Introduction

3. Every person who buys a  $u_2$  book on amazon.com and has a  $u_3$  credit card uses it  $u_3$  to pay for it  $u_2$ .

(3) shows that singular 'donkeys' can refer to **sets** of objects, i.e. **sets of values**.

4. Every boy who bought a  $u_2$  Christmas gift for a  $u_3$  girl in his class asked her  $u_3$  deskmate to wrap it  $u_2$ .

(4) shows that singular 'donkeys' can refer to a **correlation / dependency** between sets of objects, i.e. to **structure**.



# 1. Introduction

**The main proposal of the dissertation (ctd.):**

Moreover:

**structured** discourse reference enables us to account for sentences involving

complex **interactions** between **individual-level** and **modal** anaphora

by simply adding discourse referents (dref's) for possible worlds.



# 1. Introduction

**The main proposal of the dissertation (ctd.):**

In particular, we can capture the **truth-conditions** of and the **modal** and **individual-level anaphoric connections** established in discourses like:

5.
  - a. [A] man cannot live without joy.
  - b. Therefore, when he is deprived of true spiritual joys, it is necessary that he become addicted to carnal pleasures.

(Thomas Aquinas, attributed)



# 1. Introduction

## The main proposal of the dissertation (ctd.):

The interaction and parallels between individual-level and modal anaphora are more transparent in the intuitively equivalent discourse in (6) below.

6. a. If<sub>p2</sub> a<sup>u1</sup> man is alive, he<sub>u1</sub> must<sub>p2</sub> have a<sup>u2</sup> pleasure.
- b. Therefore,  
if<sub>p2</sub><sup>p5</sup> he<sub>u1</sub> does not have a<sup>u3</sup> spiritual pleasure,  
he<sub>u1</sub> must<sub>p5</sub> have a<sup>u4</sup> carnal pleasure.

# 1. Introduction

6. a. If<sub>p2</sub> a<sup>u1</sup> man is alive, he<sub>u1</sub> must<sub>p2</sub> have a<sup>u2</sup> pleasure.  
b. Therefore,  
if<sub>p2</sub><sup>p5</sup> he<sub>u1</sub> does not have a<sup>u3</sup> spiritual pleasure,  
he<sub>u1</sub> must<sub>p5</sub> have a<sup>u4</sup> carnal pleasure.

Interaction between:

- the **entailment particle** *therefore*, which embeds two **modalized conditionals**: the premise in (6a) and the conclusion in (6b);
- **donkey anaphora**: If a<sup>u1</sup> man is alive, he<sub>u1</sub> ...
- **modal subordination**:  
If<sub>p2</sub> a<sup>u1</sup> man is alive, ... if<sub>p2</sub> he<sub>u1</sub> does not have ...



# 1. Introduction: The Plan

- **2. Proposal (Part 1): The Extensional Dynamic System**

**Plural Compositional DRT (PCDRT):** Compositional DRT (Muskens 1996) extended with plural info states (following van den Berg 1996) and selective generalized quantification.

- **3. Analysis (Part 1): Multiple Donkey Sentences**

- **4. Proposal (Part 2): The Intensional Dynamic System**

**Intensional PCDRT (IP-CDRT):** PCDRT extended with dref's for possible worlds.

- **5. Analysis (Part 2): Aquinas Discourse**

- **6. Conclusion**



## 2. Plural Compositional DRT

To define and investigate **structured discourse reference**,  
I introduce a new dynamic system,

couched in **classical** (many-sorted) **type logic**

and which extends Compositional DRT (CDRT, Muskens  
1996) in two ways:

- with **plural info states**
- with **selective generalized quantification**

## 2. Plural Info States

In the spirit of Dynamic Plural Logic (van den Berg 1996),

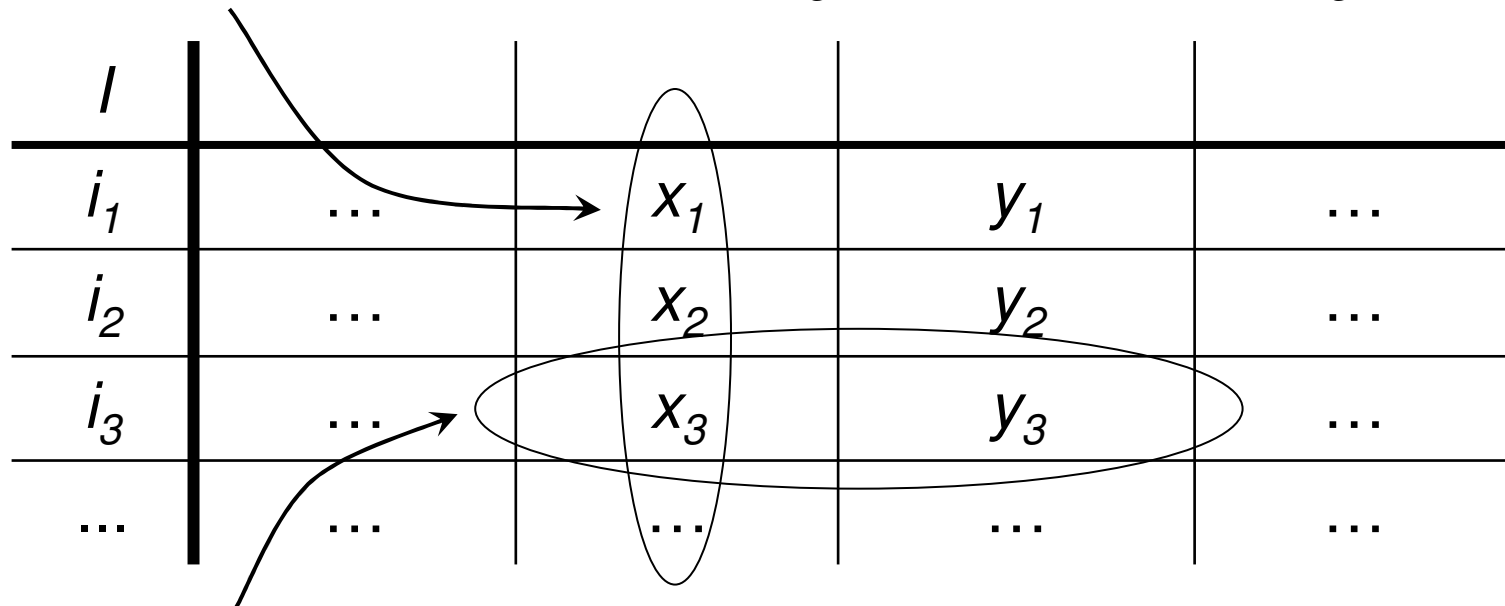
I model **information states**  $I, J$  etc. as **sets** of variable assignments  $i, j$  etc.

$I$				
$i_1$	...	$x_1$	$y_1$	...
$i_2$	...	$x_2$	$y_2$	...
$i_3$	...	$x_3$	$y_3$	...
...	...	...	...	...

## 2. Plural Info States

**Plural** information states enable us to encode discourse reference to both **values** and **structure**.

**values:** the sets  $\{x_1, x_2, x_3, \dots\}$  and  $\{y_1, y_2, y_3, \dots\}$



**structure:** the relation  $\{\langle x_1, y_1 \rangle, \langle x_2, y_2 \rangle, \langle x_3, y_3 \rangle, \dots\}$



## 2. Selective GQ's

**Selective** generalized quantifiers (**GQ's**) enable us to solve the **proportion problem**:

7. Most<sup>u</sup> house-elves who fall in love with a<sup>u'</sup> witch buy her<sup>u'</sup> an<sup>u''</sup> alligator purse.

We are **not** quantifying over **most pairs**  $\langle x, y \rangle$  where  $x$  is a house-elf that fell in love with a witch  $y$ ,  
**but** over **most house-elves**  $x$  that fell in love with some witch or other.

We are **not** quantifying over **assignments** – **unselectively**,  
**but** over **individuals** – **selectively**.



## 2. Plural States & Selective GQ's

**Together**, plural info states and selective GQ's enable us

to **compositionally** account for **weak / strong donkey ambiguities**

in a way that extends to our **multiple** donkey sentences.

**Strong** donkey readings:

2. Every farmer who owns a<sup>u</sup> donkey beats it<sub>u</sub>.

**Weak** donkey readings:

8. Every person who has a<sup>u</sup> dime will put it<sub>u</sub> in the meter.  
(Pelletier & Schubert 1989)
9. Every person who had a<sup>u</sup> credit card paid his bill with it<sub>u</sub>.  
(R. Cooper, apud Chierchia 1995: 63, (3a))



## 2. Plural Compositional DRT

We work with a Dynamic Ty2 logic, following Muskens' formulation of dynamic semantics (Muskens 1996) in Gallin's Ty2 (Gallin 1975).

Basic types:

- type  $t$ : truth-values;
- type  $e$ : individuals (atomic and non-atomic; variables:  $x, x'$  etc.);
- type  $s$ : 'variable assignments' (variables:  $i, j$  etc.).

[A suitable set of axioms ensures that the entities of type  $s$  behave as variable assignments.]



## 2. Plural Compositional DRT

- a dref for individuals  $u$  is a function of type  $se$  from 'assignments'  $i_s$  to individuals  $x_e$

(the subscripts on terms indicate their type)

Intuitively, the individual  $u_{se}i_s$  is the individual that the 'assignment'  $i$  assigns to the dref  $u$ .



## 2. Plural Compositional DRT

- dynamic info states  $I, J, K, \dots$  are **plural**: they are **sets** of 'variable assignments', i.e. they are of type  $st$
- a sentence is interpreted as a Discourse Representation Structure (DRS),

i.e. as a **relation** of type  $(st)((st)t)$  between an input info state  $I_{st}$  and an output info state  $J_{st}$ .



## 2. Plural Compositional DRT

The general form of a DRS is:

**[new drefs | conditions]**

i.e.

$\lambda I_{st} \lambda J_{st} \llbracket \text{new drefs} \rrbracket J \wedge \text{conditions} J$

For example:

$\llbracket u, u' \mid \text{person}\{u\}, \text{book}\{u\}, \text{buy}\{u, u'\} \rrbracket$

i.e.

$\lambda I_{st} \lambda J_{st} \llbracket u, u' \rrbracket J \wedge \text{person}\{u\} J \wedge \text{book}\{u\} J \wedge \text{buy}\{u, u'\} J$



## 2. Plural Compositional DRT

DRS's of the form

**[conditions]**

are tests and they are interpreted as:

$$\lambda I_{st} \lambda J_{st}. I=J \wedge \mathbf{conditions}J$$

For example:

$$[book\{u\}] := \lambda I_{st} \lambda J_{st}. I=J \wedge book\{u\}J$$



## 2. Plural Compositional DRT

- an individual dref  $u$  stores a set of individuals with respect to a plural info state  $I$ , abbreviated as:

$$uI := \{u_{se}i_s : i_s \in I_{st}\}$$

i.e.  $uI$  is the image of the set of 'assignments'  $I$  under the function  $u$ .



## 2. Compositionality

Given the underlying type logic,

compositionality at the sub-clausal level follows automatically

and standard techniques from Montague semantics (e.g. type shifting) become available.



## 2. Compositionality

In an extensional Fregean / Montagovian framework, the compositional aspect of interpretation is largely determined by the types for the extensions of the 'saturated' expressions, i.e. names and sentences.

Abbreviate them as **e** and **t**, respectively.

In PCDRT, we assign the following dynamic types to the 'meta-types' **e** and **t**:

- **t** :=  $(st)((st)t)$  (a sentence is interpreted as a DRS)
- **e** :=  $se$  (a name is interpreted as an individual dref)



## 2. Compositionality

### Extensional static logic:

- **e** is *e* (entities / individuals) and **t** is *t* (truth-values)
- the denotation of the noun **book** is of type **(et)**, i.e.  $(et)$ :

$$\mathit{book} \rightsquigarrow \lambda x_e. \mathit{book}_{et}(x)$$

- the generalized determiner **every** is of type **(et)((et)t)**, i.e.  $(et)((et)t)$

## 2. Compositionality

### Plural Compositional DRT:

- the denotation of the noun *book* is still of type **(et)**:

$$\begin{aligned} \mathit{book} &\rightsquigarrow \lambda v_e. [\mathit{book}\{v\}] \\ &\rightsquigarrow \lambda v_e. \lambda I_{st}. \lambda J_{st}. I=J \wedge \mathit{book}\{v\}J \end{aligned}$$

- the generalized determiner *every* is still of type **(et)((et)t)**:

$$\begin{aligned} \mathit{every}^u &\rightsquigarrow \lambda P'_{et}. \lambda P_{et}. [\mathbf{every}_u(P'(u), P(u))] \\ &\rightsquigarrow \lambda P'_{et}. \lambda P_{et}. \lambda I_{st}. \lambda J_{st}. I=J \wedge \mathbf{every}_u(P'(u), P(u))J \end{aligned}$$

## 2. Weak vs. Strong Indefinites

The **weak / strong** donkey ambiguity is attributed to the **indefinite articles**.

We **locally** (i.e. compositionally) decide for each indefinite article whether it receives a weak or a strong reading.

weak vs. strong ----- new dref's vs. **maximal** new dref's

**weak indefinites:**  $a^{\text{wk}:u} \rightsquigarrow \lambda P'_{\text{et}} \cdot \lambda P_{\text{et}} \cdot [u]; P'(u); P(u)$

**strong indefinites:**  $a^{\text{str}:u} \rightsquigarrow \lambda P'_{\text{et}} \cdot \lambda P_{\text{et}} \cdot \mathbf{max}^u(P'(u); P(u))$

where  $D; D' := \lambda I_{st} J_{st} \exists H_{st} (DIH \wedge DHJ)$

[i.e. ';' is dynamic conjunction and '^' is static conjunction]



## 2. Weak vs. Strong Indefinites

The only difference between a weak and a strong indefinite article is the presence vs. absence of a maximization (**max**) operator.

We can think of the indefinite article as **underspecified** with respect to the presence / absence of this operator.

The decision to introduce it or not is made at the pragmatic level, much like:

- aspectual coercion (e.g. the iterative interpretation of: *For years, John sent a letter to the company asking to be reimbursed*)
- the selection of a type for the denotation of an expression (e.g. *John and every unicorn he kissed are sunbathing on the lawn*)



## 2. Weak vs. Strong Indefinites

### The pragmatics of donkey readings.

There are **many** factors that **defeasibly** influence which reading is preferred for any given donkey sentence:

- the logical properties of determiners (Kanazawa 1994)
- world-knowledge (the 'dime' example in Pelletier & Schubert 1989; see also Geurts 2002)
- the information (focus-topic-background) structure of the sentence (Kadmon 1987, Heim 1990)
- the kind of predicates that are used (total vs. partial predicates, Krifka 1996a and references therein)
- whether the 'donkey' indefinite is referred back to by a 'donkey' pronoun (Bäuerle & Egli 1985)



## 2. Weak vs. Strong Indefinites

### The pragmatics of donkey readings.

The most conservative hypothesis is to locate the weak / strong ambiguity in the donkey items themselves (indefinites and / or pronouns)

(in PCDRT, the ambiguity / underspecification is attributed to the donkey indefinites)

and let more general and defeasible pragmatic inferences decide which reading is selected in each particular case.



## 2. Plural Compositional DRT

### Truth:

A DRS  $D$  (type  $\mathbf{t}$ ) is *true* with respect to an input info state  $I_{st}$  iff  $\exists J_{st}(DIJ)$ .



### 3. Multiple Donkey Sentences

3. Every person who buys a  $u_2$  book on amazon.com and has a  $u_3$  credit card uses it  $u_3$  to pay for it  $u_2$ .

(3) shows that singular 'donkeys' can refer to **sets** of objects, i.e. **sets of values**.

4. Every boy who bought a  $u_2$  Christmas gift for a  $u_3$  girl in his class asked her  $u_3$  deskmate to wrap it  $u_2$ .

(4) shows that singular 'donkeys' can refer to a **correlation / dependency** between sets of objects, i.e. to **structure**.



### 3. Mixed Weak & Strong Readings

3. Every <sup>$u_1$</sup>  person who buys a **str:** <sup>$u_2$</sup>  book on amazon.com and has a **wk:** <sup>$u_3$</sup>  credit card uses it <sub>$u_3$</sub>  to pay for it <sub>$u_2$</sub> .

This is a **mixed weak & strong** 'donkey' sentence,

i.e. for **every** (strong) book that any credit-card owner buys on amazon.com,

there is **some** (weak) credit card that s/he uses to pay for the book.



### 3. Mixed Weak & Strong Readings

The credit card can vary from book to book,

e.g. I can use my MasterCard to buy set theory books  
and my Visa to buy detective novels.

That is:

although it receives a **weak** reading, the indefinite  $a^{wk:u3}$   
**credit card** can introduce a non-singleton **set** of cards.

[and the **strong** indefinite  $a^{str:u2}$  **book** can also introduce  
a non-singleton **set**]

### 3. Mixed Weak & Strong Readings

3. Every<sup>*u*<sub>1</sub></sup> person who buys a<sup>**str**:*u*<sub>2</sub></sup> book on amazon.com and has a<sup>**wk**:*u*<sub>3</sub></sup> credit card uses it<sub>*u*<sub>3</sub></sub> to pay for it<sub>*u*<sub>2</sub></sub>.

The translation of (3) in classical first-order logic:

$$\begin{aligned} &\forall x(\text{person}(x) \wedge \exists y(\text{book}(y) \wedge \text{buy}(x, y)) \wedge \exists z(\text{c.card}(z) \wedge \text{have}(x, z))) \\ &\quad \rightarrow \forall y'(\text{book}(y') \wedge \text{buy}(x, y') \\ &\quad \quad \rightarrow \exists z'(\text{c.card}(z') \wedge \text{have}(x, z') \wedge \text{use\_to\_pay}(x, z', y')))) \end{aligned}$$



### 3. Mixed Weak & Strong Readings

The challenge posed by sentence (3) is to **compositionally** derive its interpretation while allowing for the fact that:

- the two donkey indefinites in the restrictor receive two distinct readings (strong and weak respectively)
- the value of the weak indefinite  $a^{wk:u3}$  *credit card* co-varies with / is dependent on the value of the strong indefinite  $a^{str:u2}$  *book* ...  
... although the strong indefinite cannot syntactically scope over the weak one,  
since both DP's are trapped in their respective conjuncts.



### 3. Donkey Anaphora to Structure

4. Every <sup>$u_1$</sup>  boy who bought a<sup>**str:** $u_2$</sup>  Christmas gift for a<sup>**str:** $u_3$</sup>  girl in his class asked her <sub>$u_3$</sub>  deskmate to wrap it <sub>$u_2$</sub> .

Both donkey indefinites are strong: we consider **every** Christmas gift and **every** girl.

The restrictor of the quantification introduces a **dependency** between the set of gifts and the set of girls:

each gift is correlated with the girl it was bought for.



### 3. Donkey Anaphora to Structure

4. Every  $u_1$  boy who bought a  $\text{str}:u_2$  Christmas gift for a  $\text{str}:u_3$  girl in his class asked her  $u_3$  deskmate to wrap it  $u_2$ .

The nuclear scope of the quantification retrieves not only the two sets of objects,  
but also the **structure** associated with them (i.e. the dependency between them):

each gift was wrapped by the deskmate of the girl that the gift was bought for.

We have donkey anaphora to **structure** in addition to donkey anaphora to **values**.



### 3. Donkey Anaphora to Structure

4. Every  $u_1$  boy who bought a  $\text{str}:u_2$  Christmas gift for a  $\text{str}:u_3$  girl in his class asked her  $u_3$  deskmate to wrap it  $u_2$ .

The dependency between gifts and girls, i.e. the **structure** associated with the two sets of objects,

is **semantically** encoded and not pragmatically inferred.

Why?



### 3. Donkey Anaphora to Structure

4. Every <sup>$u_1$</sup>  boy who bought a <sup>$\text{str}:u_2$</sup>  Christmas gift for a <sup>$\text{str}:u_3$</sup>  girl in his class asked her <sup>$u_3$</sup>  deskmate to wrap it <sup>$u_2$</sup> .

Because it is not vague / underspecified and subsequently made precise based on various extra-linguistic factors.

Suppose John buys two gifts, one for Mary and the other for Helen. The two girls are deskmates.

**(4) is true** if John asked Mary to wrap Helen's gift and Helen to wrap Mary's gift.

**(4) is not true** if John asked each girl to wrap her own gift.

[note that the *deskmate* relation is symmetric]

### 3. Donkey Anaphora to Structure

4. Every <sup>$u_1$</sup>  boy who bought a<sup>**str:** $u_2$</sup>  Christmas gift for a<sup>**str:** $u_3$</sup>  girl in his class asked her <sup>$u_3$</sup>  deskmate to wrap it <sup>$u_2$</sup> .

$I$	$u_2$ (all gifts)		$u_3$ (all girls)
$i_1$	$x_1 (=U_2i_1)$	$\xrightarrow{x_1 \text{ was bought for } y_1}$	$y_1 (=U_3i_1)$
$i_2$	$x_2 (=U_2i_2)$	$\xrightarrow{x_2 \text{ was bought for } y_2}$	$y_2 (=U_3i_2)$
$i_3$	$x_3 (=U_2i_3)$	$\xrightarrow{x_3 \text{ was bought for } y_3}$	$y_3 (=U_3i_3)$
...	...		...

For each  $i \in I$ , the gift in  $i$  was bought for the girl in  $i$ .



### 3. Donkey Anaphora to Structure

4. Every  $u_1$  boy who bought a  $\text{str}:u_2$  Christmas gift for a  $\text{str}:u_3$  girl in his class asked her  $u_3$  deskmate to wrap it  $u_2$ .

The strong donkey indefinites introduce both

- **values**, i.e. the set of gifts  $\{x_1, x_2, \dots\}$  and the set of girls  $\{y_1, y_2, \dots\}$ ,

and

- **structure**, i.e. for each 'assignment'  $i \in I$ , the gift  $u_2 i$  was bought for girl  $u_3 i$ .



### 3. Donkey Anaphora to Structure

4. Every <sup>$u_1$</sup>  boy who bought a<sup>**str:** $u_2$</sup>  Christmas gift for a<sup>**str:** $u_3$</sup>  girl in his class asked her <sub>$u_3$</sub>  deskmate to wrap it <sub>$u_2$</sub> .

When we process the nuclear scope of the quantification, we are **anaphoric** to both **values** and **structure**,

i.e. we elaborate on the dependency between  $u_3$  and  $u_2$  introduced in the restrictor:

we require each 'assignment'  $i \in I$  to be such that the deskmate of girl  $u_3 i$  was asked to wrap gift  $u_2 i$ .



### 3. Mixed Weak & Strong Readings

3. Every <sup>$u_1$</sup>  person who buys a<sup>**str:** $u_2$</sup>  book on amazon.com and has a<sup>**wk:** $u_3$</sup>  credit card uses it <sub>$u_3$</sub>  to pay for it <sub>$u_2$</sub> .

The interpretation of sentence (3) is similar, except for two important differences:

- the indefinite **a<sup>wk: $u_3$</sup>  credit card** is weak;
- the structural dependency between books and credit cards is implicit in the restrictor and is explicitly established only in the nuclear scope.

# 3. Mixed Weak & Strong Readings

3. Every  $u_1$  person who buys a **str:** $u_2$  book on amazon.com and has a **wk:** $u_3$  credit card uses it  $u_3$  to pay for it  $u_2$ .

$I$	$U_2$ (all books)		$U_3$ (some cards)
$i_1$	$x_1 (=U_2 i_1)$	$\xrightarrow{x_1 \text{ is somehow correlated with } y_1}$	$y_1 (=U_3 i_1)$
$i_2$	$x_2 (=U_2 i_2)$	$\xrightarrow{x_2 \text{ is somehow correlated with } y_2}$	$y_2 (=U_3 i_2)$
$i_3$	$x_3 (=U_2 i_3)$	$\xrightarrow{x_3 \text{ is somehow correlated with } y_3}$	$y_3 (=U_3 i_3)$
...	...		...



### 3. Mixed Weak & Strong Readings

3. Every <sup>$u_1$</sup>  person who buys a **str:** <sup>$u_2$</sup>  book on amazon.com and has a **wk:** <sup>$u_3$</sup>  credit card uses it <sub>$u_3$</sub>  to pay for it <sub>$u_2$</sub> .

By the time we are done processing the restrictor:

- we introduce the **maximal** value for  $u_2$
- we **non-deterministically** introduce some **suitable value** for  $u_3$
- we **non-deterministically** introduce some **structure** correlating the values of  $u_2$  and  $u_3$



### 3. Mixed Weak & Strong Readings

3. Every <sup>$u_1$</sup>  person who buys a<sup>**str:** $u_2$</sup>  book on amazon.com and has a<sup>**wk:** $u_3$</sup>  credit card uses it <sub>$u_3$</sub>  to pay for it <sub>$u_2$</sub> .

The nuclear scope is again anaphoric to both values and structure,

i.e. we test that the non-deterministically introduced value for  $u_3$  and the non-deterministically introduced structure associating  $u_3$  and  $u_2$  satisfy the nuclear scope condition.



### 3. Mixed Weak & Strong Readings

3. Every <sup>$u_1$</sup>  person who buys a **str:** <sup>$u_2$</sup>  book on amazon.com and has a **wk:** <sup>$u_3$</sup>  credit card uses it <sub>$u_3$</sub>  to pay for it <sub>$u_2$</sub> .

That is,

the nuclear scope **elaborates** on the unspecified dependency between  $u_3$  and  $u_2$  introduced in the restrictor of the quantification:

for each 'assignment'  $i \in I$ , we test that the credit card  $u_3 i$  is used to pay for the book  $u_2 i$ .



### 3. Mixed Weak & Strong Readings

3. Every<sup>*u*<sub>1</sub></sup> person who buys a<sup>*str*:*u*<sub>2</sub></sup> book on amazon.com and has a<sup>*wk*:*u*<sub>3</sub></sup> credit card uses it<sub>*u*<sub>3</sub></sub> to pay for it<sub>*u*<sub>2</sub></sub>.

The credit cards co-vary with / are dependent on the books and introducing such a dependency does not require the strong indefinite *a*<sup>*str*:*u*<sub>2</sub></sup> **book** to scope over the weak indefinite *a*<sup>*wk*:*u*<sub>3</sub></sup> **credit card** ...

... which wouldn't be possible because the two DP's are trapped within their respective conjuncts.



## 4. Aquinas Discourse

5. a. [A] man cannot live without joy.
- b. Therefore, when he is deprived of true spiritual joys, it is necessary that he become addicted to carnal pleasures.

I will focus on only one of the meaning dimensions of this discourse, namely:

the **entailment** relation established by *therefore* between the **modal** premise (5a) and the **modal** conclusion in (5b).

(for the meaning multidimensionality associated with *therefore*, see for example Grice 1975 and Potts 2003)



## 4. Aquinas Discourse

We want to capture:

- o the meaning of the entailment particle *therefore*, which:
  - relates the **content** of the premise (5a) and the **content** of the conclusion in (5b)
  - requires the latter to be **entailed** by the former.

The **content** of a sentence: its **truth-conditions**, i.e. the set of possible worlds in which the sentence is **true**.

**Entailment:** content **inclusion**, i.e. (5a) entails (5b) iff for any world  $w$ , if (5a) is true in  $w$ , so is (5b).



## 4. Aquinas Discourse

And we also want to capture:

- o the **meanings** of premise (5a) and conclusion (5b)

The **meaning** of a sentence: its **context-change potential**,

which encodes both **content** (truth-conditions) and **anaphoric potential**.



## 4. Aquinas Discourse

Thus, on the one hand, we are interested in the **contents** of (5a) and (5b).

They are both **modal quantifications**.

(5a) involves a circumstantial modal base (Kratzer 1981) and asserts that,

in view of the circumstances, i.e. given that God created man in a particular way,

as long as a man is alive, he must find some thing or other pleasurable.



## 4. Aquinas Discourse

(5b) involves the same modal base and elaborates on the preceding modal quantification:

in view of the circumstances,

if a man is alive and he has no spiritual pleasure, he must have a carnal pleasure.

We need to make the contents of (5a) and (5b) **accessible in discourse** so that the entailment particle *therefore* can relate them.



## 4. Aquinas Discourse

On the other hand, we are interested in the **anaphoric potential** of (5a) and (5b),

i.e. in the anaphoric connections between them,

which we need in order to establish their contents.

These connections are explicitly represented in discourse (6) below, which is intuitively equivalent to (5).



## 4. Aquinas Discourse

6. a. If a<sup>str:u1</sup> man is alive,

he<sub>u1</sub> must find something<sup>wk/str:u2</sup> pleasurable /

he<sub>u1</sub> must have a<sup>wk/str:u2</sup> pleasure.

b. Therefore,

if he<sub>u1</sub> does not have a<sup>wk/str:u3</sup> spiritual pleasure,

he<sub>u1</sub> must have a<sup>wk/str:u4</sup> carnal pleasure.



## 4. Aquinas Discourse

The strong donkey indefinite  $a^{\text{str}:u_1}$  *man* in the antecedent of the conditional in (6a) introduces the maximized dref  $u_1$ , which is anaphorically retrieved by:

- the pronoun  $he_{u_1}$  in the consequent of (6a) (donkey anaphora)
- the pronoun  $he_{u_1}$  in the antecedent of (6b)

The latter is an instance of **modal subordination** (Roberts 1989), i.e. an instance of **simultaneous modal** and **individual-level** anaphora (Frank 1996, Geurts 1999 and Stone 1999), that is...



## 4. Aquinas Discourse

That is,

the conditional in (6b) covertly duplicates the antecedent of the conditional in (6a), i.e. it asserts that:

if **a<sup>str:u1</sup> man is alive** and he<sub>u1</sub> doesn't have any<sup>wk/str:u3</sup> spiritual pleasure, he<sub>u1</sub> must have a<sup>wk/str:u4</sup> carnal one.

I will analyze the simpler and more transparent discourse in (6) instead of the naturally occurring discourse in (5).



## 4. Aquinas Discourse

6. a. If<sup>p2</sup> a<sup>str:u1</sup> man is alive,  
he<sub>u1</sub> must<sub>p2</sub> find something<sup>wk/str:u2</sup> pleasurable /  
he<sub>u1</sub> must<sub>p2</sub> have a<sup>wk/str:u2</sup> pleasure.
- b. Therefore,  
if<sub>p2</sub><sup>p5</sup> he<sub>u1</sub> does not have a<sup>wk/str:u3</sup> spiritual pleasure,  
he<sub>u1</sub> must<sub>p5</sub> have a<sup>wk/str:u4</sup> carnal pleasure.



## 4. Aquinas Discourse

### Summary – the problem:

when we **compositionally** assign meanings to:

- the modalized conditional in (6a), i.e. the premise,
- the modalized conditional in (6b), i.e. the conclusion,
- the entailment particle *therefore*,

we have to capture:

- the **intuitively correct truth-conditions** of the whole discourse and
- the **modal** and **individual-level anaphoric connections** between the two sentences of the discourse and within each one of them.



## 4. Intensional PCDRT

We extend Plural CDRT with dref's for possible worlds.

We work with a Dynamic Ty3 logic.

Basic types:

- type  $t$ : truth-values;
- type  $e$ : individuals (variables:  $x, x'$  etc.);
- type  $s$ : 'variable assignments' (variables:  $i, j$  etc.);
- type  $w$ : possible worlds (variables:  $w, w'$  etc.).



## 4. Intensional PCDRT

- a dref for individuals  $u$  is a function of type  $se$  from 'assignments'  $i_s$  to individuals  $x_e$ .

Intuitively, the individual  $u_{se}i_s$  is the individual that the 'assignment'  $i$  assigns to the dref  $u$ .

- a dref for possible worlds  $p$  is a function of type  $sw$  from 'assignments'  $i_s$  to worlds  $w_w$ .

Intuitively, the world  $p_{sw}i_s$  is the world that the 'assignment'  $i$  assigns to the dref  $p$ .

## 4. Intensional PCDRT

- an individual dref  $u$  stores a set of individuals with respect to a plural info state  $I$ , abbreviated as:

$$uI := \{u_{se}i_s : i_s \in I_{st}\}$$

- a dref  $p$  stores a set of worlds, i.e. a **proposition**, with respect to an info state  $I$ , abbreviated as:

$$pI := \{p_{sw}i_s : i_s \in I_{st}\}$$



## 4. Intensional PCDRT

**Propositional** dref's have two uses:

- they store **contents**,

e.g. the content of the premise (6a) and the content of the conclusion (6b);

- they store **possible scenarios** (in the sense of Stone 1999),

e.g. the set of worlds introduced by the conditional antecedent in (6a).



## 4. Intensional PCDRT

We use **plural info states** to store sets of individuals and propositions

instead of simply using dref's for sets of individuals or sets of possible worlds

(their types would be  $s(et)$  and  $s(\mathbf{wt})$ )

because we need to store in our information states both the **values** assigned to various dref's and the **structure** associated with those values.



## 4. Intensional PCDRT

Consider the **multiple plural anaphora** in (10) and the parallel **modal subordination** in (11).

10. a. Every<sup>u</sup> man saw a<sup>u'</sup> woman.  
b. They<sub>u</sub> greeted them<sub>u'</sub>.

11. a. A<sup>u</sup> wolf might<sup>p</sup> enter the cabin.  
b. It<sub>u</sub> would<sub>p</sub> attack John.



## 4. Intensional PCDRT

We do not simply have anaphora to sets, but anaphora to **structured** sets:

if man  $m_1$  saw woman  $n_1$  and  $m_2$  saw  $n_2$ ,

(10b) is interpreted as asserting that  $m_1$  greeted  $n_1$ , not  $n_2$ , and that  $m_2$  greeted  $n_2$ , not  $n_1$ .

The structure of the greeting is the same as the structure of the seeing.

# 4. Intensional PCDRT

$I$	$u$ (men)		$u'$ (women)	...
$i_1$	$m_1 (=ui_1)$	$\xrightarrow{m_1 \text{ saw } n_1}$	$n_1 (=u'i_1)$	...
$i_2$	$m_2 (=ui_2)$	$\xrightarrow{m_2 \text{ saw } n_2}$	$n_2 (=u'i_2)$	...
$i_3$	$m_3 (=ui_3)$	$\xrightarrow{m_3 \text{ saw } n_3}$	$n_3 (=u'i_3)$	...
...	...		...	...

For each  $i \in I$ , the man in  $i$  saw the woman in  $i$ .



## 4. Intensional PCDRT

Similarly, (11b) asserts that:

if a wolf entered the cabin, it would attack John,

i.e. if a black wolf  $x_1$  enters the cabin in world  $w_1$  and a white wolf  $x_2$  enters the cabin in world  $w_2$ ,

then  $x_1$  attacks John in  $w_1$ , not in  $w_2$ , and  $x_2$  attacks John in  $w_2$ , not in  $w_1$ .

## 4. Intensional PCDRT

$I$	...	$u$ (wolves)	$p$ (worlds)	...
$i_1$	...	$x_1 (=ui_1)$	$w_1 (=pi_1)$	...
$i_2$	...	$x_2 (=ui_2)$	$w_2 (=pi_2)$	...
$i_3$	...	$x_3 (=ui_3)$	$w_3 (=pi_3)$	...
...	...	...	...	...

For each  $i \in I$ , the wolf in  $i$  enters the cabin in the possible world in  $i$ .



## 4. Intensional PCDRT

Thus, in the spirit of Stone (1999),

**modal anaphora** is analyzed in Intensional PCDRT by means of dref's for **static** modal objects.

Plural info states enable us to keep these static objects simple (unlike Stone 1999):

modal anaphora is anaphora to dref's  $p$  for **structured sets of possible worlds**.



## 4. Intensional PCDRT

We also need plural info states to capture structured anaphora between the premise(s) and the conclusion of *therefore* discourses like (12) and (13).

12. a. Every<sup>*u*</sup> man saw a<sup>*u'*</sup> woman.  
b. Therefore, they<sub>*u*</sub> noticed them<sub>*u'*</sub>.
13. a. A<sup>*u*</sup> wolf might<sup>*p*</sup> enter the cabin.  
b. It<sub>*u*</sub> would<sub>*p*</sub> see John<sup>*u'*</sup>.  
c. Therefore, it<sub>*u*</sub> would<sub>*p*</sub> notice him<sub>*u'*</sub>.



## 4. Compositionality

In an intensional Fregean / Montagovian framework, the compositional aspect of interpretation is determined by

the types for the extensions of the 'saturated' expressions, i.e. sentences ( $\mathbf{t} := (st)((st)t)$ ) and names ( $\mathbf{e} := se$ )

plus the type that allows us to build intensions out of these extensions. Abbreviate it as  $\mathbf{s}$ .

In Intensional PCDRT, we assign the following dynamic type to the 'meta-type'  $\mathbf{s}$ :

- $\mathbf{s} := \mathbf{sw}$  (i.e. we use world dref's to build intensions)

# 4. Compositionality

## Intensional PCDRT:

- the denotation of the noun *book* is of type  $\mathbf{e(st)}$ :

$$book \rightsquigarrow \lambda v_e. \lambda q_s. [book_q\{v\}],$$

where *book* is of type  $\mathbf{e(wt)}$

- the generalized determiner *every* is of type  $\mathbf{(e(st))((e(st))(st))}$ :

$$every^u \rightsquigarrow \lambda P'_{\mathbf{e(st)}}. \lambda P_{\mathbf{e(st)}}. \lambda q_s. [{}_q \mathbf{det}_u(P'(u)(q), P(u)(q))]$$

# 5. Aquinas Discourse

## 14. a. CONTENT<sup>p1</sup>:

**if**<sup>p2</sup> (a<sup>str:u1</sup> man<sub>p2</sub> is alive<sub>p2</sub>);

**must**<sup>p3</sup><sub>p1,μ,ω</sub>(p<sub>2</sub>, p<sub>3</sub>); he<sub>u1</sub> has<sub>p3</sub> a<sup>u2</sup> pleasure<sub>p3</sub>.

## b. THEREFORE<sup>p4</sup><sub>p\*,μ\*,ω\*</sub>(p<sub>1</sub>, p<sub>4</sub>):

**if**<sup>p5</sup> (p<sub>5</sub> ∈ p<sub>2</sub>; **not**(he<sub>u1</sub> has<sub>p5</sub> a<sup>u3</sup> spiritual pleasure<sub>p5</sub>));

**must**<sup>p6</sup><sub>p4,μ,ω</sub>(p<sub>5</sub>, p<sub>6</sub>); he<sub>u1</sub> has<sub>p6</sub> a<sup>u4</sup> carnal pleasure<sub>p6</sub>.

The representation in (14) is basically a **network of structured anaphoric connections.**



## 5. Aquinas Discourse

### The conditional in (14a):

- the morpheme *if* introduces a propositional dref  $p_2$  that stores the content of the antecedent;  
we need this distinct dref because the antecedent in (6b) is anaphoric to it (due to modal subordination)
- the indefinite  $a^{\text{str}:u_1}$  *man* introduces an individual dref  $u_1$ , which is later retrieved:
  - (i) by the pronoun  $he_{u_1}$  in (6a), i.e. by donkey anaphora;
  - (ii) by the pronoun  $he_{u_1}$  in the antecedent of (6b), i.e. by modal subordination.



## 5. Aquinas Discourse

The conditional in (14a) (ctd.):

- the modal verb *must* in the consequent contributes a tripartite quantificational structure and it relates three propositional dref's:  $p_1$ ,  $p_2$  and  $p_3$ .

$p_1$ : it stores the content of the whole modalized conditional.

$p_2$ : it was introduced by the antecedent;

it is anaphorically retrieved by *must*;

it provides the restrictor of the modal quantification.



## 5. Aquinas Discourse

The conditional in (14a) (ctd.):

$p_3$ : it is introduced by the modal *must*;

it is the nuclear scope of the modal quantification;

the modal verb constrains it to contain the set of **ideal** worlds among the set of  $p_2$ -worlds ...

... ideal relative to the  $p_1$ -worlds, a **circumstantial** modal base (MB)  $\mu$  and an **empty** ordering source (OS)  $\omega$ .

- finally, we test that the set of ideal worlds stored in  $p_3$  satisfies the remainder of the consequent.



## 5. Aquinas Discourse

The entailment particle *therefore*:

- it relates **contents** and not meanings;
- it is analyzed as a modal relation expressing **logical consequence**
- thus, discourse (5/6) is analyzed as:  
  
a modal quantification that relates (the contents of) two embedded modal quantifications,  
  
the second of which is modally subordinated to the first.



## 5. Aquinas Discourse

The entailment particle *therefore* (ctd.):

- *therefore* contributes a **necessity** modal relation and introduces a tripartite quantificational structure:

the restrictor is  $p_1$  (the content of the premise)

the nuclear scope is the newly introduced dref  $p_4$ , which stores the set of ideal  $p_1$ -worlds ...

... ideal relative to the dref  $p^*$  (the dref for the actual world  $w^*$ ), an **empty** MB  $\mu^*$  and an **empty** OS  $\omega^*$ .



## 5. Aquinas Discourse

The entailment particle *therefore* (ctd.):

- the MB  $\mu^*$  and the OS  $\omega^*$  are **empty** because *therefore* is interpreted as **logical consequence**;
- since  $\mu^*$  and  $\omega^*$  are empty, the dref  $p_4$  is identical to  $p_1$ ;
- analyzing *therefore* as an instance of modal quantification predicts that we can interpret it relative to different MB's and OS's.

This prediction is borne out.



## 5. Aquinas Discourse

The entailment particle *therefore* (ctd.):

- *therefore* expresses **causal consequence** in:

Reviewers are usually people who would have been poets, historians, biographers, etc., if they could; they have tried their talents at one or the other, and have failed; **therefore** they turn critics.

(Samuel Taylor Coleridge, *Lectures on Shakespeare and Milton*)



## 5. Aquinas Discourse

The entailment particle *therefore* (ctd.):

- *therefore* seems to express a form of **practical inference** in:

We cannot put the face of a person on a stamp unless said person is deceased. My suggestion, **therefore**, is that you drop dead.

(attributed to J. Edward Day; letter, never mailed, to a petitioner who wanted himself portrayed on a postage stamp)



## 5. Aquinas Discourse

**The conditional in (14b):** is interpreted like the conditional in (14a), except that its antecedent is anaphoric to the antecedent of the conditional in (14a), i.e. to the dref  $p_2$ ;

- the dref  $p_5$  is a **structured** subset of  $p_2$ , symbolized as  $p_5 \in p_2$ ;
- we need the **structured inclusion**  $p_5 \in p_2$  because we want  $p_5$  to preserve the structure associated with the  $p_2$ -worlds,  
i.e. to preserve in  $p_5$  the previously established correlation between  $p_2$ -worlds and the  $u_1$ -men in them.



## 5. Aquinas Discourse

The conditional in (14b) (ctd.):

The modal verb *must* in (14b):

- it is anaphoric to  $p_5$ ;
- it introduces the set of worlds  $p_6$  containing all the ideal  $p_5$ -worlds – ideal relative to the  $p_4$ -worlds,  $\mu$  and  $\omega$ , i.e. the same as the MB and the OS in the premise (14a);
- finally, it checks that in each ideal  $p_6$ -world, all its associated  $u_1$ -men have a carnal pleasure.



# 6. Conclusion

**The main proposal of the dissertation:**

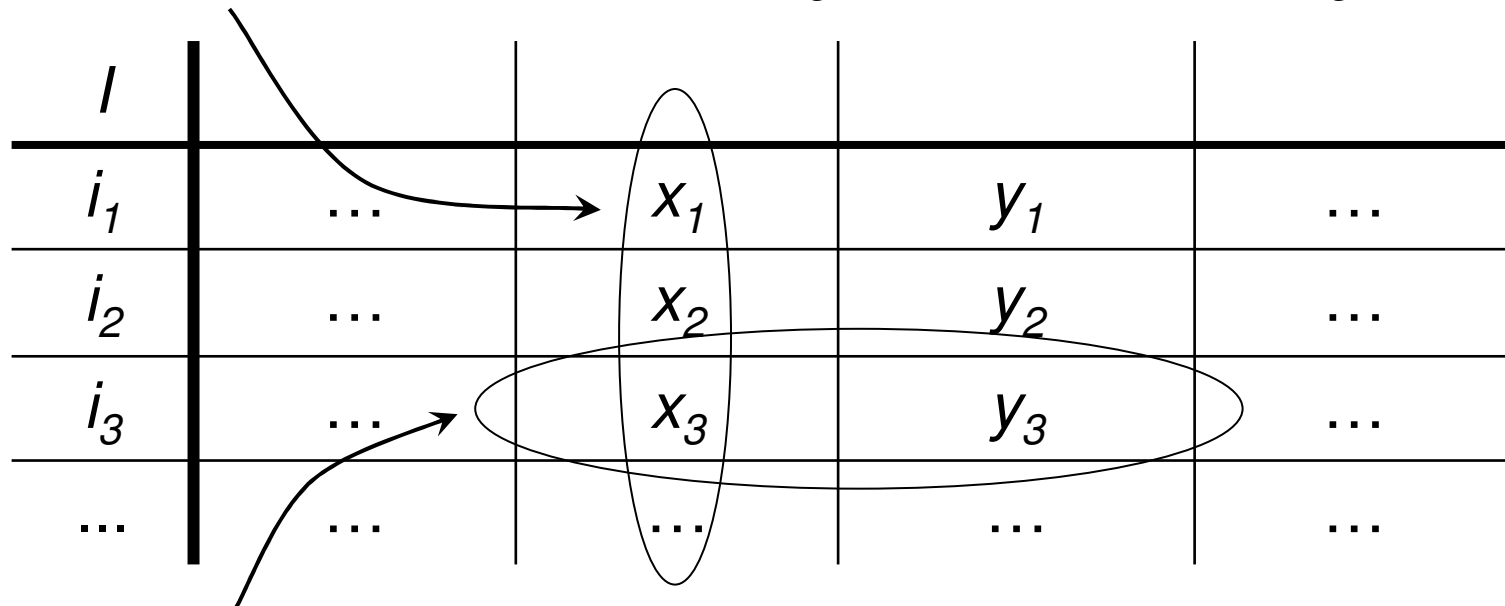
**Nominal** and **modal** expressions introduce possibly non-singleton **sets of objects** (individuals and possible worlds) and these sets are **semantically correlated** in discourse.

Discourse reference involves **two equally important components** with essentially **the same interpretive dynamics**: reference to **values** (the sets of objects) and reference to **structure** (the correlation / dependency between such sets).

# 6. Conclusion

**Plural** information states enable us to encode discourse reference to both **values** and **structure**.

**values:** the sets  $\{x_1, x_2, x_3, \dots\}$  and  $\{y_1, y_2, y_3, \dots\}$



**structure:** the relation  $\{\langle x_1, y_1 \rangle, \langle x_2, y_2 \rangle, \langle x_3, y_3 \rangle, \dots\}$



## 6. Conclusion

To define and investigate **structured** discourse reference, I have introduced a new dynamic system couched in classical (many-sorted) type logic:

### **(Intensional) Plural CDRT.**

Given the underlying type logic, compositionality at the sub-clausal level follows automatically and standard techniques from Montague semantics (e.g. type shifting) become available.



## 6. Conclusion

**Plural CDRT** enables us to account for sentences that contain multiple instances of singular donkey anaphora that are semantically correlated, i.e.

### **Mixed weak & strong donkey sentences:**

3. Every person who buys a  $u_2$  book on amazon.com and has a  $u_3$  credit card uses it $_{u_3}$  to pay for it $_{u_2}$ .

### **Donkey Anaphora to Structure:**

4. Every boy who bought a  $u_2$  Christmas gift for a  $u_3$  girl in his class asked her $_{u_3}$  deskmate to wrap it $_{u_2}$ .



## 6. Conclusion

**Singular & intra-sentential** donkey anaphora provides a much stronger argument for the idea that **plural info states** are **semantically** necessary

- compared to arguments based on **plural & cross-sentential** anaphora (van den Berg 1996, Krifka 1996b, Nouwen 2003 among others)

[The parallel between the possibility of a pragmatic account of cross-sentential anaphora to value in

*A<sup>u</sup> man came in. He<sub>u</sub> sat down.*

and the possibility of a pragmatic account of cross-sentential anaphora to structure in

*Every<sup>u</sup> man saw a<sup>u'</sup> woman. They<sub>u</sub> greeted them<sub>u'</sub>.]*



## 6. Conclusion

Choice and / or Skolem Functions can in principle be used to capture donkey anaphora to structure, but ...

... they have to have variable arity depending on how many simultaneous donkey anaphors there are,

i.e. their arity is determined by the **discourse context** and we should encode this context dependency in the **info state** and not in the representation of a lexical item (be it the donkey pronoun and / or the donkey indefinite).



## 6. Conclusion

**Intensional Plural CDRT** enables us to account for sentences involving complex interactions between:

- the entailment particle *therefore*
- modalized conditionals
- donkey anaphora
- modal subordination

5. a. [A] man cannot live without joy.  
b. Therefore, when he is deprived of true spiritual joys, it is necessary that he become addicted to carnal pleasures.



## 6. Conclusion

The Aquinas discourse is analyzed as a network of structured anaphoric connections:

the meaning (and validity) of the argument emerges as a consequence of the intertwined individual-level and modal anaphora.

Modal subordination is basically analyzed as quantifier domain restriction via structured modal anaphora.



## 6. Conclusion

The present investigation is located at the intersection of two research programs:

- the unification of Montague semantics and dynamic semantics (see Muskens 1996 among others)

Intensional PCDRT takes this program one step further:

it unifies – in classical type logic – the static Lewis (1973) / Kratzer (1981) analysis of modal quantification and van den Berg's Dynamic Plural Logic.



## 6. Conclusion

- the investigation of the anaphoric and quantificational parallels across domains – in particular, between the individual and modal domains

(see Stone 1999, Bittner 2001 and Schlenker 2005 among others, building on the parallel between the individual and temporal domains in Partee 1973, 1984)

e.g. individual-level and modal dref's have parallel types in Intensional PCDRT,

in contrast to Geurts (1999) and Frank (1996) among others, who use dref's for contexts (i.e. for info states) to analyze modal anaphora.



## 6. Conclusion

Given that Intensional PCDRT unifies Montague and dynamic semantics, we can extend it in the usual ways to account for the diverse range of naturally occurring *therefore* discourses:

- *therefore* can relate two deontic modal quantifications:

It is necessary for me to establish a winner image.  
**Therefore**, I have to beat somebody.

(attributed to Richard Nixon)



## 6. Conclusion

- *therefore* can be anaphoric to a modal quantification involving a comparative correlative :

If you commit a big crime then you are crazy, and the more heinous the crime the crazier you must be. **Therefore** you are not responsible, and nothing is your fault.

(attributed to Peggy Noonan)

- *therefore* can interact with VP cataphora:

I can, **therefore** I blog.

([http://normblog.typepad.com/normblog/2006/03/i\\_can\\_therefore.html](http://normblog.typepad.com/normblog/2006/03/i_can_therefore.html))



## 6. Conclusion

- *therefore* can be embedded in an attitude report:

This is the site that Darlene, the woman who emailed [m]e, runs. Her blog is more popular than [m]y blog. You might think that I would **therefore** not like her, but you would be wrong. I love Darlene, even if she has the best blogger website address.

(<http://whatwouldjb.blogspot.com/2006/04/what-else-would-jesus-blog.html>)

This discourse seems to be interpreted as follows:

*you might think that [ I would not like her because her blog is more popular than mine ].*



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