Kamp & Reyle 1993, Ch. 1 (1)
Introduction to Discourse Representation Theory

• BASIC PATTERNS OF DISCOURSE ANAPHORA

In Ch. 1 K&R analyze discourse anaphora to names and indefinite NPs in simple affirmative and negated sentences like (1)–(5) and failure of anaphora in (6).

(1) Jones owns Ulysses. It fascinates him.
(2) Jones owns a Porsche. It fascinates him.
(3) A stockbroker who knows Bill likes him.
(4) Jones owns a Porsche. He does not like it.
(5) Jones doesn't own Ulysses. He likes it (however).
(6) Jones doesn't own a Porsche. He likes it (however). (* anaphoric *it*)

• BASIC IDEA (Karttunen 1976)

Discourse anaphora is mediated by discourse referents (*drefs*). These are introduced by NPs (superscripted **x**, **y**, etc below) and may have their 'lifespan' cut off by higher operators such as negation. Within their lifespan, dref's can be picked up by anaphoric pronouns (subscripted **x**, **y**), as in (1′)–(5′). The problem with (6′) is that the lifespan of a dref set up by an indefinite, $a^{\mathbf{y}}$, under negation is limited to the scope of the negation operator — $it_{\mathbf{y}}$ comes too late.

(1′) Jones$^{\mathbf{x}}$ owns Ulysses$^{\mathbf{y}}$. It$_{\mathbf{y}}$ fascinates him$_{\mathbf{x}}$.
(2′) Jones$^{\mathbf{x}}$ owns a$^{\mathbf{y}}$ Porsche. It$_{\mathbf{y}}$ fascinates him$_{\mathbf{x}}$.
(3′) A$^{\mathbf{x}}$ stockbroker who knows Bill$^{\mathbf{y}}$ likes him$_{\mathbf{y}}$.
(4′) Jones$^{\mathbf{x}}$ owns a$^{\mathbf{y}}$ Porsche. He$_{\mathbf{x}}$ does not like it$_{\mathbf{y}}$.
(5′) Jones$^{\mathbf{x}}$ does*n't* own Ulysses$^{\mathbf{y}}$. He$_{\mathbf{x}}$ likes it$_{\mathbf{y}}$ (however).
(6′) Jones$^{\mathbf{x}}$ does*n't* [own a$^{\mathbf{y}}$ Porsche]. He$_{\mathbf{x}}$ likes it$_{\mathbf{y}}$ (however). ([…] = lifespan of dref set up by $a^{\mathbf{y}}$)

• FORMALIZATION (K&R 1993, Ch. 1, elaborating Kamp 1981)

Explicate Karttunen's intuitive idea by defining a suitable formal language, *Discourse Representation Theory* (DRT), and a *translation algorithm* from a relevant fragment of English into DRT (K&R Construction Rules pp. 121–4).

DRT Syntax (= K&R Definition 1.4.1, p. 110)

(i) A *Discourse Representation Structure* (*DRS*) K *confined to a vocabulary* V and *dref set* R is a pair, consisting of a possibly empty subset $U_K \subseteq R$ and a possibly empty set Con_K of DRS-conditions confined to V and R.

(ii) A *DRS-condition confined to* V *and* R is an expression of one of the following forms:
(a) $\mathbf{x} = \mathbf{y}$, where $\mathbf{x}, \mathbf{y} \in R$
(b) $\pi(\mathbf{x})$, where $\mathbf{x} \in R$ and π is an individual constant from V
(c) $\eta(\mathbf{x})$, where $\mathbf{x} \in R$ and η is a unary predicate (corresponding to a common noun) from V
(d) $\mathbf{x}\zeta$, where $\mathbf{x} \in R$ and ζ is a unary predicate (corresponding to an intransitive verb) from V
(e) $\mathbf{x}\xi\mathbf{y}$, where $\mathbf{x}, \mathbf{y} \in R$ and ξ is a binary predicate from V
(f) $\neg K$, where K is a DRS confined to V and R.

Note:
Only *proper DRS's* — i.e. DRS's where no dref's are *free* in the sense of Definition 1.4.2 (p. 111) — are interpreted in DRT.

DRT Models (≡ K&R Definition 1.2.1, p. 94)

A *model* M *for a vocabulary* V is a triple $\langle U_M, Name_M, Pred_M \rangle$ consisting of:

(i) M's *universe* U_M

(ii) a function $Name_M$ which assigns an element of U_M to each indidual constant of V.
For each constant $\mathbf{c} \in V$, $Name_M(\mathbf{c})$ is called the *bearer of* **c** *according to* M.

(iii) a function $Pred_M$ which assigns:
- a subset of U_M to each 1-place predicate constant of V
- a set of *n*-tuples of elements of U_M to each *n*-place predicate constant of V ($n \geq 2$)

For each predicate constant $\mathbf{P} \in V$, $Pred_M(\mathbf{P})$ is called the *extension of* **P** *in* M.

DRT Semantics (≡ K&R Definitions 1.4.4–5, p. 112–4)

Let $K = \langle U_K, Con_K \rangle$ be a proper DRS confined to V and R, let $M = \langle U_M, Name_M, Pred_M \rangle$ be a DRT model for V, and let f be an *embedding from* R *into* M (i.e. f is a function such that $Dom(f) \subseteq R$ and $Ran(f) \subseteq U_M$).

(i) for any DRS condition $\gamma \in Con_K$, f *verifies* γ in M iff
(a) γ is of the form $\mathbf{x} = \mathbf{y}$ and $f(\mathbf{x}) = f(\mathbf{y})$.
(b) γ is of the form $\pi(\mathbf{x})$ and $f(\mathbf{x}) = Name_M(\pi)$.
(c) γ is of the form $\eta(\mathbf{x})$ and $f(\mathbf{x}) \in Pred_M(\eta)$.
(d) γ is of the form $\mathbf{x}\zeta$ and $f(\mathbf{x}) \in Pred_M(\zeta)$.
(e) γ is of the form $\mathbf{x}\xi\mathbf{y}$ and $\langle f(\mathbf{x}), f(\mathbf{y}) \rangle \in Pred_M(\xi)$
(f) γ is of the form $\neg K'$ and there is no embedding g from R into M such that
- g extends f (i.e. $f \subseteq g$)
- $Dom(g) = Dom(f) \cup U_{K'}$
- g verifies K′ in M

(ii) f *verifies* the DRS K in M iff f verifies each condition $\gamma \in Con_K$ in M.

(iii) K is *true in* M iff there is an embedding f from R into M such that $Dom(f) = U_K$ and f verifies K in M.

Translation from English into DRT (= K&R Construction Rules, pp. 86, 121–4)

Most of K&R’s construction rules require little comment except for CR.PRO, the rule for anaphoric pronouns. Note that this rule requires the antecedent to be an *accessible dref* — a formalization of Karttunen’s idea of limited lifespan. K&R define dref accessibility as a syntactic relation in terms of an auxiliary notion of *DRS subordination*:

DRS Subordination (= K&R Definition 1.4.10, pp. 119–120)

Let K and K′ be DRS’s.

(i) K is *immediately subordinate to* K′ iff $\neg K \in Con_{K'}$

(ii) K is *subordinate to* K′, $K < K'$, iff
either (a) K is immediately subordinate to K′
or (b) there is a DRS K″ such that K″ is subordinate to K′ and K is immediately subordinate to K″.

(iii) K is *weakly subordinate to* K′, $K \leq K'$, iff $K = K'$ or $K < K'$.

Dref Accessibility (= K&R Definition 1.4.11, pp. 120)

Let K be a DRS, **x** a dref, and γ a DRS-condition.
We say that **x** is *accessible from* γ in K iff, for some K′ and K″, (i) $K'' \leq K' \leq K$, (ii) $\gamma \in Con_{K''}$, and (iii) $\mathbf{x} \in U_{K'}$.

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Karttunen, L. (1976) ‘Discourse Referents’. In J. McCawley (ed.) *Syntax and Semantics* **7**, pp. 363–85. Academic Press, New York.

Kamp & Reyle 1993, Ch. 1 (2)
Verifying DRSs for Simple Discourses

- DRT SEMANTICS OF (1)

(1) Jones owns Ulysses. It fascinates him.

- *DRS* K_1 for (1): (derived in class)

x y u v
Jones(x)
Ulysses(y)
x owns y
u = y
v = x
u fascinates v

- DRT *model* M_1 for the vocabulary of (1): (K&R Def. 1.2.1)

$M_1 = \langle U_{M1}, Name_{M1}, Pred_{M1}\rangle$,

where

$U_{M1} = \{a, b\}$

$Name_{M1}(Jones) = a$ $Name_{M1}(Ulysses) = b$

$Pred_{M1}(owns) = \{\langle a, b\rangle\}$ $Pred_{M1}(fascinates) = \{\langle b, a\rangle\}$

- The following *embedding* f_1 from {x, y, u, v} into M_1 *verifies* K_1 *in* M_1: (K&R Def. 1.4.4)

$f_1(x) = f_1(v) = a$ $f_1(y) = f_1(u) = b$

Specifically, f_1 verifies every condition of K_1 in M_1 as follows:

Jones(x)	verified by clause (b):	$f_1(x) = a = Name_{M1}(Jones)$
Ulysses(y)	verified by clause (b):	$f_1(y) = b = Name_{M1}(Ulysses)$
x owns y	verified by clause (e):	$\langle f_1(x), f_1(y)\rangle = \langle a, b\rangle \in Pred_{M1}(owns) = \{\langle a, b\rangle\}$
u = y	verified by clause (a):	$f_1(u) = b = f_1(y)$
v = x	verified by clause (a):	$f_1(v) = a = f_1(x)$
u fascinates v	verified by clause (e):	$\langle f_1(u), f_1(v)\rangle = \langle b, a\rangle \in Pred_{M1}(fascinates) = \{\langle b, a\rangle\}$

- Therefore, K_1 is *true in* M_1. (K&R Def. 1.4.5)

- DRT SEMANTICS OF (2)

(2) Jones owns a Porsche. It fascinates him.

- *DRS* K_2 for (2): (DRT construction rules)

x y u v
Jones(x) Porsche(y) x owns y u = y v = x u fascinates v

- DRT *model* M_2 for the vocabulary of (2): (K&R Def. 1.2.1)

$M_2 = \langle U_{M2}, Name_{M2}, Pred_{M2} \rangle$,

where

$U_{M2} = \{a, b\}$

$Name_{M2}(Jones) = a$

$Pred_{M2}(Porsche) = \{b\}$ $Pred_{M2}(owns) = \{\langle a, b\rangle\}$ $Pred_{M2}(fascinates) = \{\langle b, a\rangle\}$

- The following *embedding* f_2 from {x, y, u, v} into M_2 *verifies* K_2 *in* M_2: (K&R Def. 1.4.4)

$f_2(x) = f_2(v) = a$ $f_2(y) = f_2(u) = b$

Specifically, f_2 verifies every condition of K_2 in M_2 as follows:

Jones(x)	verified by clause (b):	$f_2(x) = a = Name_{M2}(Jones)$
Porsche(y)	verified by clause (c):	$f_2(y) = b \in Pred_{M2}(Porsche) = \{b\}$
x owns y	verified by clause (e):	$\langle f_2(x), f_2(y)\rangle = \langle a, b\rangle \in Pred_{M2}(owns) = \{\langle a, b\rangle\}$
u = y	verified by clause (a):	$f_2(u) = b = f_2(y)$
v = x	verified by clause (a):	$f_2(v) = a = f_2(x)$
u fascinates v	verified by clause (e):	$\langle f_2(u), f_2(v)\rangle = \langle b, a\rangle \in Pred_{M2}(fascinates) = \{\langle b, a\rangle\}$

- Therefore, K_2 is *true in* M_2. (K&R Def. 1.4.5)

- DRT SEMANTICS OF (3)

(3) A stockbroker who knows Bill likes him.

- *DRS* K_3 for (3): (DRT construction rules)

x y u
stockbroker(x) Bill(y) x knows y u = y x likes u

- DRT *model* M_3 for the vocabulary of (3): (K&R Def. 1.2.1)

$M_3 = \langle U_{M3}, Name_{M3}, Pred_{M3}\rangle$,

where

$U_{M3} = \{a, b\}$

$Name_{M3}(Bill) = b$

$Pred_{M3}(stockbroker) = \{a\}$ $Pred_{M3}(knows) = \{\langle a, b\rangle\}$ $Pred_{M3}(likes) = \{\langle a, b\rangle\}$

- The following *embedding* f_3 from {x, y, u} into M_3 *verifies* K_3 *in* M_3: (K&R Def. 1.4.4)

$f_3(x) = a$ $f_3(y) = f_3(u) = b$

Specifically, f_3 verifies every condition of K_3 in M_3 as follows:

stockbroker(x)	verified by clause (c):	$f_3(x) = a \in Pred_{M3}(stockbroker) = \{a\}$
Bill(y)	verified by clause (b):	$f_3(y) = b = Name_{M3}(Bill)$
x knows y	verified by clause (e):	$\langle f_3(x), f_3(y)\rangle = \langle a, b\rangle \in Pred_{M3}(knows) = \{\langle a, b\rangle\}$
u = y	verified by clause (a):	$f_3(u) = b = f_3(y)$
x likes u	verified by clause (e):	$\langle f_3(x), f_3(u)\rangle = \langle a, b\rangle \in Pred_{M3}(likes) = \{\langle a, b\rangle\}$

- Therefore, K_3 is *true in* M_3. (K&R Def. 1.4.5)

- DRT SEMANTICS OF (4)

(4) Jones owns a Porsche. He does not like it.

- *DRS* K_4 for (4): (DRT construction rules)

```
 _____________________
|  x   y   u          |
|                     |
|  Jones(x)           |
|  Porsche(y)         |
|  x owns y           |
|  x = u              |
|      ___________    |
|     |    v      |   |
|  ¬  |  v = y    |   |
|     |  u like v |   |
|     |___________|   |
|_____________________|
```

- DRT *model* M_4 for the vocabulary of (4): (K&R Def. 1.2.1)

  $M_4 = \langle U_{M4}, Name_{M4}, Pred_{M4} \rangle$,

  where

  $U_{M4} = \{a, b\}$

  $Name_{M4}(Jones) = a$

  $Pred_{M4}(Porsche) = \{b\}$ $Pred_{M4}(owns) = \{\langle a, b\rangle\}$ $Pred_{M4}(like) = \{\langle a, a\rangle\}$

- The following *embedding* f_4 from {x, y, u} into M_4 *verifies* K_4 *in* M_4: (K&R Def. 1.4.4)

  $f_4(x) = f_4(u) = a$ $f_4(y) = b$

  Specifically, f_4 verifies every condition of K_4 in M_4 as follows:

Jones(x)	verified by clause (b):	$f_4(x) = a = Name_{M4}(Jones)$
Porsche(y)	verified by clause (c):	$f_4(y) = b \in Pred_{M4}(Porsche) = \{b\}$
x owns y	verified by clause (e):	$\langle f_4(x), f_4(y)\rangle = \langle a, b\rangle \in Pred_{M4}(owns) = \{\langle a, b\rangle\}$
x = u	verified by clause (a):	$f_4(x) = a = f_4(u)$
¬ [v | v = y, u like v]	verified by clause (f):	there is no embedding g into M_4 such that: • $f_4 \subseteq g$, i.e., $g(x) = g(u) = a$ and $g(y) = b$ • $Dom(g) = \{x, u, y\} \cup \{v\} = \{x, u, y, v\}$ • $g(v) = g(y)$, i.e., $g(v) = b$ $\langle g(u), g(v)\rangle = \langle a, b\rangle \in Pred_{M4}(like) = \{\langle a, a\rangle\}$ (No such g because the last condition cannot be met.)

- Therefore, K_4 is *true in* M_4. (K&R Def. 1.4.5)

NOTE: More generally, K_4 will be true in any DRT model in which there is no Porsche that (the bearer of the name) Jones owns and likes.

• DRT SEMANTICS OF (5)

(5) Jones doesn't own Ulysses. He likes it (however).

- *DRS* K_5 for (5): (DRT construction rules)

```
 x  y  u  v

 Jones(x)
 Ulysses(y)
     __________
 ¬  | x own y  |
    |__________|

 u = x
 v = y
 u likes v
```

- DRT *model* M_5 for the vocabulary of (5): (K&R Def. 1.2.1)

  $M_5 = \langle U_{M5}, Name_{M5}, Pred_{M5} \rangle$,

  where

  $U_{M5} = \{a, b, c\}$

  $Name_{M5}(Jones) = a$ $\quad$ $Name_{M5}(Ulysses) = b$

  $Pred_{M4}(owns) = \{\langle c, b \rangle\}$ $\quad$ $Pred_{M4}(likes) = \{\langle a, b \rangle\}$

- The following *embedding* f_5 from {x, y, u, v} into M_5 *verifies* K_5 *in* M_5: (K&R Def. 1.4.4)

  $f_5(x) = f_5(u) = a$ $\quad$ $f_5(y) = f_5(v) = b$

  Specifically, f_5 verifies every condition of K_5 in M_5 as follows:

  Jones(x) verified by clause (b): $f_5(x) = a = Name_{M5}(Jones)$

  Ulysses(y) verified by clause (b): $f_5(y) = b = Name_{M5}(Ulysses)$

  ¬ | x own y | verified by clause (f): there is no embedding g into M_5 such that:
  - $f_5 \subseteq g$, i.e., $g(x) = g(u) = a$ and $g(y) = g(v) = b$
  - $Dom(g) = \{x, u, y, v\} \cup \{ \} = \{x, u, y, v\}$
  - $\langle g(x), g(y) \rangle = \langle a, b \rangle \in Pred_{M4}(own) = \{\langle c, b \rangle\}$
    (No such g because the last condition cannot be met.)

  u = x verified by clause (a): $f_5(u) = a = f_5(x)$

  v = y verified by clause (a): $f_5(v) = b = f_5(y)$

  u likes v verified by clause (e): $\langle f_5(u), f_5(v) \rangle = \langle a, b \rangle \in Pred_{M4}(likes) = \{\langle a, b \rangle\}$

- Therefore, K_5 is *true in* M_5. (K&R Def. 1.4.5)

- DRT SEMANTICS OF (6)

(6) Jones doesn't own a Porsche. He likes it (however).

- *DRS* K_6 for (6): (DRT construction rules)

```
x   u   v

Jones(x)
       ___________
      |     y     |
  ¬   | Porsche(y)|
      | x own y   |
      |___________|

u = x
v = x
u likes v
```

NOTE: y is **not** accessible to v, x is the only accessible antecedent. [Therefore, this discourse is wrongly assigned the same DRS as 'Jones doesn't own a Porsche. He likes himself.']

- DRT *model* M_6 for the vocabulary of (6): (K&R Def. 1.2.1)

$M_6 = \langle U_{M6}, Name_{M6}, Pred_{M6} \rangle$,

where

$U_{M6} = \{a, b, c\}$

$Name_{M6}(Jones) = a$

$Pred_{M6}(Porsche) = \{b\}$ $Pred_{M6}(own) = \{\langle c, b \rangle\}$ $Pred_{M6}(like) = \{\langle a, a \rangle\}$

- The following *embedding* f_6 from {x, u, v} into M_6 *verifies* K_6 *in* M_6: (K&R Def. 1.4.4)

$f_6(x) = f_6(u) = f_6(v) = a$

Specifically, f_6 verifies every condition of K_6 in M_6 as follows:

Jones(x)	verified by clause (b):	$f_6(x) = a = Name_{M6}(Jones)$
¬ [y | Porsche(y), x own y]	verified by clause (f):	there is no embedding g into M_6 such that: • $f_6 \subseteq g$, i.e., g(x) = g(u) = g(v) = a • Dom(g) = {x, u, v} ∪ {y} = {x, u, v, y} • $g(y) \in Pred_{M6}(Porsche) = \{b\}$, i.e., g(y) = b $\langle g(x), g(y) \rangle = \langle a, b \rangle \in Pred_{M4}(like) = \{\langle a, a \rangle\}$ (No such g because the last condition cannot be met.)
u = x	verified by clause (a):	$f_6(u) = a = f_6(x)$
v = x	verified by clause (a):	$f_6(v) = a = f_6(x)$
u likes v	verified by clause (e):	$\langle f_6(u), f_6(v) \rangle = \langle a, a \rangle \in Pred_{M6}(like) = \{\langle a, a \rangle\}$

- Therefore, K_6 is *true in* M_6. (K&R Def. 1.4.5)

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- DRT SEMANTICS OF (1)

(1) Jones owns Ulysses. It fascinates him.

- *DRS* K_1 for (1): (derived in class)

x y u v
Jones(x) Ulysses(y) x owns y u = y v = x u fascinates v

- DRT *model* M_1 for the vocabulary of (1): (K&R Def. 1.2.1)

$M_1 = \langle U_{M1}, Name_{M1}, Pred_{M1}\rangle$,

where

$U_{M1} = \{a, b\}$
$Name_{M1}(Jones) = a$ $Name_{M1}(Ulysses) = b$
$Pred_{M1}(owns) = \{\langle a, b\rangle\}$ $Pred_{M1}(fascinates) = \{\langle b, a\rangle\}$

- The following *embedding* f_1 from {x, y, u, v} into M_1 *verifies* K_1 *in* M_1: (K&R Def. 1.4.4)

$f_1(x) = f_1(v) = a$ $f_1(y) = f_1(u) = b$

Specifically, f_1 verifies every condition of K_1 in M_1 as follows:

Jones(x)	verified by clause (b):	$f_1(x) = a = Name_{M1}(Jones)$
Ulysses(y)	verified by clause (b):	$f_1(y) = b = Name_{M1}(Ulysses)$
x owns y	verified by clause (e):	$\langle f_1(x), f_1(y)\rangle = \langle a, b\rangle \in Pred_{M1}(owns) = \{\langle a, b\rangle\}$
u = y	verified by clause (a):	$f_1(u) = b = f_1(y)$
v = x	verified by clause (a):	$f_1(v) = a = f_1(x)$
u fascinates v	verified by clause (e):	$\langle f_1(u), f_1(v)\rangle = \langle b, a\rangle \in Pred_{M1}(fascinates) = \{\langle b, a\rangle\}$

- Therefore, K_1 is *true in* M_1. (K&R Def. 1.4.5)