Philosophical and linguistic applications of team semantics

Class 5: Dependence Logic

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Linguistic applications team semantics

Team semantics: formulas interpreted wrt a set of points of evaluation (a team) rather than single ones [Hodges 1997, Väänänen 2007]

Early application

IF-LOGIC: branching in natural language [Henkin 1959, Hintikka 1973]

(1) a. Some$_y$ relative of each$_x$ villager and some$_w$ relative of each$_z$ townsman hate each other
b. $(\forall x)(\exists y)(\forall z)(\exists w/\forall x)R(x,z,y,w)$

Status of branching controversial in logical-linguistic literature:

- Branching generalized quantifiers (Barwise79, Westerståhl87, van Benthem89)
- Doubts about evidence for branching in linguistic literature (Fauconnier75)
- Schlenker06: branching in DE positions & exceptional scope of indefinites (Brasoveanu & Farkas11)

(2) a. If some relative of mine dies, I will inherit a house $[\exists/\to]$ & $[\to/\exists]$
b. If every relative of mine dies, I will inherit a house only $[\to/\forall]$

A recent application

DEPENDENCE LOGIC: exceptional scope & (non)specificity across languages ⇐

- MA & Marco Degano, 2022. "(Non-)specificity across languages: constancy, variation, v-variation." SALT 32

Linguistic applications team semantics

INQUISITIVE (EPISTEMIC) LOGIC: questions and attitude verbs

[Ciardelli & Roelofsen 2011, 2015; Ciardelli, Groenendijk & Roelofsen 2018]

(3) a. Aicha knows/#wonders/believes that it is raining

b. Aicha knows/wonders/#believes whether it is raining

BILATERAL STATE-BASED MODAL LOGIC (BSML): free choice and ignorance inferences [Anttila 2021; MA 2022; Anttila, MA & Yang 2023]

(4) a. You may go to the beach *or* to the cinema $\rightsquigarrow$ You may go to the beach

b. The prize is in the attic *or* in the garden $\rightsquigarrow$ Speaker doesn't know where

Main hypothesis: non-classical inferences result from a tendency in human cognition to avoid empty representations (neglect-zero); (New conjecture: the ability to split states is acquired late)

BSML: Propositional Modal Logic + NE (+ F) [$M, s \models$ NE iff $s \neq \emptyset$]

Common idea

Teams as information states, i.e., sets of alternative possible situations compatible with the agent's belief/information [Stalnaker 1978]

Teams as information states: propositional case

Team: a set of valuations / possible worlds

(5)

p	q
1	0
1	1

$\Rightarrow$ the info that p is true and that q might be true or false

(6)

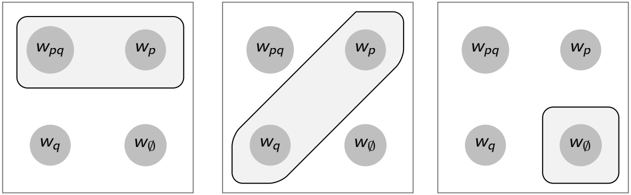
p	q
1	0
0	1

$\Rightarrow$ the info that either only p is true or only q

(7)

p	q
0	0

$\Rightarrow$ the info that p and q are both false [$\Leftarrow$ *max info*]



(a) Team 1 (b) Team 2 (c) Team 3

Teams as information states: two-sorted f-o case

Team: a set of assignments in a two-sorted framework with designated variable v ranging over possible worlds

(8)

v
w_p
w_q

$\Rightarrow$ the info that only p is true or only q [$\Leftarrow$ *initial team*]

(9)

v	x
w_1	a
w_2	a
w_3	a

$\Rightarrow$ value of x is known

(10)

v	x
w_1	a
w_2	b
w_3	c

$\Rightarrow$ unknown but specific

v	x
w_1	a
w_1	b
w_1	c

$\Rightarrow$ non-specific

Linguistically relevant distinctions that we can characterise using dependence atoms

A wealth of indefinites

Cross-linguistically, we witness a wealth of indefinite forms:

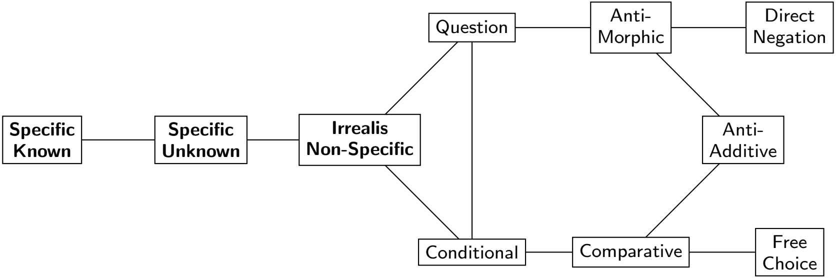
- English: *some*, *any*, *no*, . . .
- Italian: *qualunque*, *nessuno*, *(un) qualche*, . . .
- Dutch: *iets*, *enig*, *wie dan ook*, *niets*, . . .
- German: *ein*, *irgendein*, . . .
- Russian: *koe-*, *-to*, *-nibud*, . . .
- Spanish: *algún*, *cualquiera*, *ningun*, . . .
- Náhuatl/Mexicano: *yeka*, *sente*, *olgo*, . . .
- Kannada: *-oo*, *-aadaruu*, . . .
- Mandarin: *shenme*, . . .
- . . .

Why this variety? What do all these forms have in common? How to account for their differences in meaning and distribution?

Today's focus: scopal (specific vs non-specific) and epistemic (known vs unknown) uses of indefinites.

Haspelmath Map

Haspelmath (1997)'s map: a useful typological tool to capture the functional distribution of indefinites



Haspelmath's map (extended, Aguilar et al 2011)

Haspelmath's implicational map makes predictions about

(i) possible indefinite forms cross-linguistically (only those occupying a contiguous area on the map);

(ii) their possible diachronic development (contiguous functions developed first).

Scopal vs epistemic specificity (Farkas, 1996)

Scopal specificity

Indefinites marked for specificity tend to presuppose the existence of their referent, and introduce discourse referents:

(11) Ali wants to visit an Italian city.

a. **Specific**: There is a specific Italian city which Ali wants to visit [$\exists x / \Box$]

b. **Non-specific**: Ali wants to visit an Italian city, any Italian city would do [$\Box / \exists x$]

[Continuation *It is in the North-East close to Venice* only possible for (11a)]

Epistemic specificity

Indefinites marked for (un)known signal that the speaker does (not) know the identity of the referent

(12) A student called.

a. **Known**: The speaker knows which student called.

b. **Unknown**: The speaker doesn't know which student called.

Specific Known, Specific Unknown and Non-Specific

(13) a. **Specific known (SK):** scopal specific & epistemic specific

b. **Specific unknown (SU):** scopal specific & epistemic non-specific

c. **Non-specific (NS):** scopal non-specific

Illustration

(14) Ali wants to visit <u>an Italian city</u>.

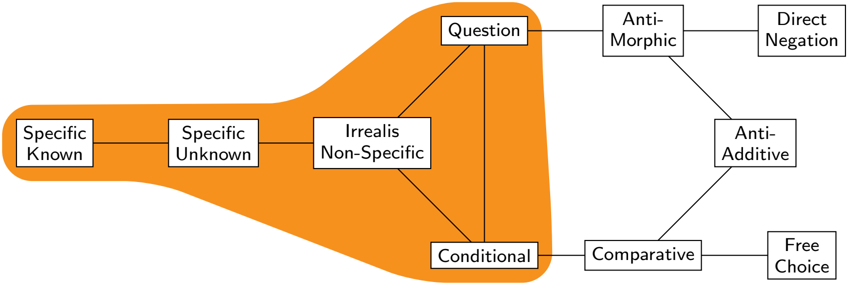
a. **SK**: There is a specific city which Ali wants to visit, and the speaker knows which

b. **SU**: There is a specific city which Ali wants to visit, but the speaker doesn't know which

c. **NS**: Ali wants to visit an Italian city, any Italian city would do

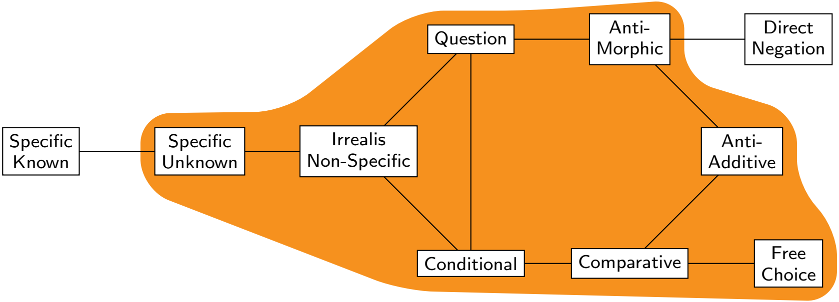
Cross-linguistically, languages developed lexicalized forms with restricted distributions with respect to these uses.

Haspelmath Map



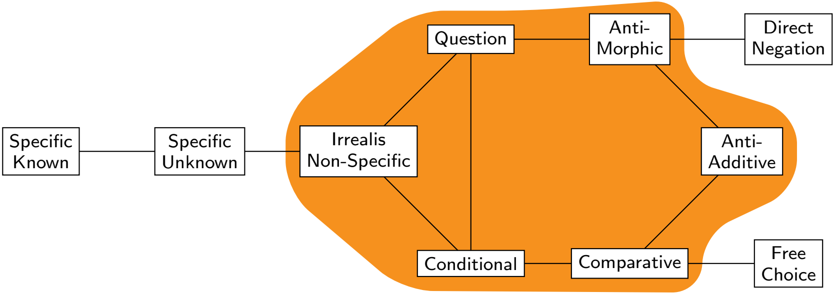
English *someone*

Haspelmath Map



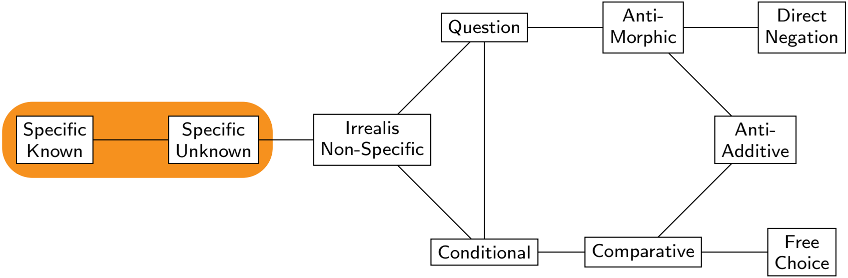
German *irgend-*

Haspelmath Map



Russian *nibud'*

Haspelmath Map



Kazakh *älde*

Our Goals

(1) a logical characterization of the specific known (SK), specific unknown (SU) and non-specific (NS) functions; and a principled explanation of their position on Haspelmath's implicational map;

(2) a formal account of the variety of marked indefinites encoding SK, SU, and NS: specific known, epistemic, specific and non-specific indefinites; and their properties.

(3) explanation of observed diachronic pathway from non-specific to epistemic.

Main idea: Indefinites are sensitive to *dependence* and *non-dependence* relationships in their value assignments (building on insights from Brasoveanu and Farkas 2011; Farkas and Brasoveanu 2020).

Implementation: Two-sorted team semantics with dependence atoms.

References

MA & Marco Degano, 2022. "(Non-)specificity across languages: constancy, variation, v-variation." SALT 32

Marco Degano, 2024, "Indefinites and their values." PhD thesis, ILLC, University of Amsterdam

Siyuan Cao, 2023, "Wh-indefinites in Mandarin: The case of *shenme*" MSc Logic thesis, ILLC, University of Amsterdam

Marked Indefinites

Possible **marked indefinites** based on Specific Known (SK), Specific Unknown (SU) and Non-specific (NS):

TYPE OF INDEFINITE	FUNCTIONS SK	SU	NS	EXAMPLE
(i) unmarked	✓	✓	✓	Italian *qualcuno*
(ii) specific	✓	✓	✗	Georgian *-ghats*
(iii) non-specific	✗	✗	✓	Russian *-nibud*
(iv) epistemic	✗	✓	✓	German *irgend-*
(v) specific known	✓	✗	✗	Russian *koe-*
(vi) SK + NS	✓	✗	✓	unattested
(vii) specific unknown	✗	✓	✗	Kannada *-oo*

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(iii) non-specific	✗	✗	✓	Russian *-nibud*
(iv) epistemic	✗	✓	✓	German *irgend-*
(v) specific known	✓	✗	✗	Russian *koe-*
(vi) SK + NS	✓	✗	✓	unattested
(vii) specific unknown	✗	✓	✗	Kannada *-oo*

How to capture this variety?

Marked Indefinites

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(i) unmarked	✓	✓	✓	Italian *qualcuno*
(ii) **specific**	✓	✓	✗	Georgian *-ghats*
(iii) **non-specific**	✗	✗	✓	Russian *-nibud*
(iv) **epistemic**	✗	✓	✓	German *irgend-*
(v) **specific known**	✓	✗	✗	Russian *koe-*
(vi) SK + NS	✓	✗	✓	unattested
(vii) specific unknown	✗	✓	✗	Kannada *-oo*

Why (ii)-(v) common? Why (vi) unattested? Why (vii) rare?

Marked Indefinites

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(iii) non-specific	✗	✗	✓	Russian *-nibud*
(iv) epistemic	✗	✓	✓	German *irgend-*
(v) specific known	✓	✗	✗	Russian *koe-*
(vi) SK + NS	✓	✗	✓	unattested
(vii) specific unknown	✗	✓	✗	Kannada *-oo*

How to derive the restricted distribution of non-specific indefinites (ungrammatical in episodic sentences)?

Marked Indefinites

Possible **marked indefinites** based on Specific Known (SK), Specific Unknown (SU) and Non-specific (NS):

TYPE OF INDEFINITE	FUNCTIONS			EXAMPLE
	SK	SU	NS	
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(iv) epistemic	✗	✓	✓	German *irgend-*
(v) specific known	✓	✗	✗	Russian *koe-*
(vi) SK + NS	✓	✗	✓	unattested
(vii) specific unknown	✗	✓	✗	Kannada *-oo*

How to characterize the obligatory ignorance inferences typical of epistemic indefinites? And the knowledge inference typical of specific known indefinites?

Marked Indefinites

Possible **marked indefinites** based on Specific Known (SK), Specific Unknown (SU) and Non-specific (NS):

TYPE OF INDEFINITE	FUNCTIONS SK	SU	NS	EXAMPLE
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(iv) epistemic	✗	✓	✓	German *irgend-*
(v) specific known	✓	✗	✗	Russian *koe-*
(vi) SK + NS	✓	✗	✓	unattested
(vii) specific unknown	✗	✓	✗	Kannada *-oo*

Indefinites in general display exceptional scope behaviour. Why? How to account for their exceptional scope? What scope configurations are possible for marked indefinites (e.g. narrow, intermediate, wide)?

Language & Teams

Team semantics: formulas are interpreted wrt **sets** of evaluation points (*teams*) rather than single points. Here a team is a set of assignment functions.

We use a **two-sorted team semantics** framework:

(i) possible worlds introduced as second sort of entities (with special **world variables** which can be quantified over);

(ii) v as **designated variable** over worlds, representing alternative ways things might be (epistemic possibilities).

Examples:

(15) Everybody smiles $\mapsto \forall x S(x, v)$ & Everybody must smile $\mapsto \forall w \forall x S(x, w)$

Language:

$z ::= z_d \mid z_w$

$\phi ::= P(\vec{z}) \mid \neg P(\vec{z}) \mid \phi \vee \psi \mid \phi \wedge \psi \mid \exists_{strict} z\phi \mid \exists_{lax} z\phi \mid \forall z\phi \mid dep(\vec{z}, z) \mid var(\vec{z}, z)$

A **model** is a triple $M = \langle D, W, I \rangle$, where D is a set of individuals, W a set of worlds and I an interpretation function.

A function f with finite domain $Z = Z_d \cup Z_w$ is an **assignment** (wrt model $M = \langle D, W, I \rangle$) iff there are f_1, f_2: $f = f_1 \cup f_2$ & $f_1 \in D^{Z_d}$ & $f_2 \in W^{Z_w}$

Team:

Given a model $M = \langle D, W, I \rangle$ and a finite set of variables Z, a team T over M with domain Z is a set of assignments with domain Z

Teams as information states: initial teams

Teams represent information states of speakers.

In initial teams only factual information is represented.

Initial team: A team T is *initial* iff $Dom(T) = \{v\}$.

- The *designated world variable* v captures the speaker's epistemic possibilities.
- Teams where v receives only one value are teams of *maximal information*.

Illustration

[w_{Pa} means $\langle I_M(a), w_{Pa}\rangle \in I_M(R)$]

(16) $\begin{array}{c} \text{v} \\ \hline w_{Pa} \\ w_{Pb} \end{array}$ $\Rightarrow$ the info that Pa is true or Pb [$\Leftarrow$ *initial team*]

(17) $\begin{array}{c} \text{v} \\ \hline w_{Pa} \end{array}$ $\Rightarrow$ the info that Pa is true [$\Leftarrow$ *initial team of max info*]

Felicitous sentence: A sentence is *felicitous/grammatical* if there is an initial team which supports it.

Teams as information states: adding discourse information

In initial teams only factual information is represented.

Discourse information is then added by operations of assignment extensions (Galliani 2015).

v	x	w	y	...
v_1	a	w_1	b_1	...
v_2	a	w_2	b_2	...
...	a	...	...	...
v_n	a	w_n	b_n	...

Illustration: non-initial teams

(18)

v	x
w_1	a
w_2	a
w_3	a

⇒ value of x is known

(19)

v	x
w_1	a
w_2	b
w_3	c

⇒ unknown but specific

v	x
w_1	a
w_1	b
w_1	c

⇒ non-specific

Linguistically relevant distinctions that we can characterise using dependence & variation atoms

Universal Extension

$$T[z_*] = \{i[e_*/z_*] : i \in T \text{ and } e_* \in Dom_*(M)\}$$

[where $* \in \{d, w\}$ & $Dom_d(M) = D$ & $Dom_w(M) = W$]

A **universal extension** of a team T with y, denoted by $T[y]$, amounts to consider all assignments that extend or differ from the ones in T only with respect to the value of y.

v	T
v_1	i_1
v_2	i_2

v	y	$T[y]$
v_1	d_1	i_{11}
	d_2	i_{12}
v_2	d_1	i_{21}
	d_2	i_{22}

($D = \{d_1, d_2\}$. Universal extensions are unique. They allow *branching*.)

Strict Functional Extension

$$T[h_s/z_*] = \{i[h_s(i)/z_*] : i \in T\}, \text{for some strict function } h_s : T \to Dom_*(M)$$

A **strict functional extension** of a team T with y, $T[h_s/y]$, assigns only one value to y for each original assignment in T.

v	T
v_1	i_1
v_2	i_2

With $D = \{d_1, d_2\}$ we have 4 possible strict functional extensions. No branching allowed:

v	y	$T[h_1/y]$
$v_1 \longrightarrow$	d_1	i_{11}
$v_2 \longrightarrow$	d_1	i_{21}

v	y	$T[h_2/y]$
$v_1 \longrightarrow$	d_2	i_{12}
$v_2 \longrightarrow$	d_2	i_{21}

x	y	$T[h_3/y]$
$v_1 \longrightarrow$	d_1	i_{11}
$v_2 \longrightarrow$	d_2	i_{21}

x	y	$T[h_4/y]$
$v_1 \longrightarrow$	d_2	i_{12}
$v_2 \longrightarrow$	d_1	i_{21}

Lax Functional Extension

$T[f_l/z_*] = \{i[e_*/z_*] : i \in T \ \& \ e_* \in f_l(i)\}$, for some lax function $f_l : T \to \wp(Dom_*(M)) \backslash \{\varnothing\}$

A **lax functional extension** of a team T with y, $T[f_l/y]$, amounts to assign one or more values to y for each original assignment in T.

v	T
v_1	i_1
v_2	i_2

v	y	$T[f_l/y]$
$v_1 \longrightarrow$	d_2	i_{12}
$v_2 \longrightarrow$	d_1	i_{21}
$v_2 \longrightarrow$	d_2	i_{22}

(With $D = \{d_1, d_2\}$, 9 possible lax functional extensions. Branching allowed.)

Semantic Clauses

$$
\begin{array}{lcl}
M, T \models P(z_1, \ldots, z_n) & \Leftrightarrow & \forall j \in T : \langle j(z_1), \ldots, j(z_n) \rangle \in I(P^n) \\
M, T \models \neg P(z_1, \ldots, z_n) & \Leftrightarrow & \forall j \in T : \langle j(z_1), \ldots, j(z_n) \rangle \notin I(P^n) \\
M, T \models \phi \wedge \psi & \Leftrightarrow & M, T \models \phi \text{ and } M, T \models \psi \\
M, T \models \phi \vee \psi & \Leftrightarrow & T = T_1 \cup T_2 \text{ for teams } T_1 \text{ and } T_2 \text{ s.t. } \\
 & & M, T_1 \models \phi \text{ and } M, T_2 \models \psi \\
M, T \models \forall z \phi & \Leftrightarrow & M, T[z] \models \phi \\
M, T \models \exists_{\text{strict}} z \phi & \Leftrightarrow & \text{there is a strict } h_s : M, T[h_s/z] \models \phi \\
M, T \models \exists_{\text{lax}} z \phi & \Leftrightarrow & \text{there is a lax } f_l : M, T[f_l/z] \models \phi \\
M, T \models dep(\vec{z}, u) & \Leftrightarrow & \text{for all } i, j \in T : i(\vec{z}) = j(\vec{z}) \Rightarrow i(u) = j(u) \\
M, T \models var(\vec{z}, u) & \Leftrightarrow & \text{there is } i, j \in T : i(\vec{z}) = j(\vec{z}) \; \& \; i(u) \neq j(u)
\end{array}
$$

Dependence and Variation Atoms

Dependence & variation atoms model (non-)dependency patterns between variables' values (Väänänen 2007; Galliani 2015):

Dependence Atom:

$$M, T \models dep(\vec{z}, u) \Leftrightarrow \text{ for all } i, j \in T : i(\vec{z}) = j(\vec{z}) \Rightarrow i(u) = j(u)$$

Variation Atom:

$$M, T \models var(\vec{z}, u) \Leftrightarrow \text{ there is } i, j \in T : i(\vec{z}) = j(\vec{z}) \;\&\; i(u) \neq j(u)$$

T	x	y	z	l
i	a_1	b_1	c_1	d_1
j	a_1	b_1	c_2	d_1
k	a_3	b_2	c_3	d_1

$dep(x, y)$ ✓ $var(x, z)$ ✓

$dep(\varnothing, l)$ ✓ $var(\varnothing, x)$ ✓

$dep(y, z)$ ✗ $var(x, y)$ ✗

Indefinites as Existentials

We propose that:

1. Indefinites are **strict existentials** ($\exists_{\text{s(trict)}} x$).
2. They are interpreted *in-situ*.

Dependence atoms will be used to model the exceptional scope behaviour of indefinites, by specifying how their value (co-)varies with other operators.

Dependence and variation atoms will be used to capture the variety of marked indefinite forms, by specifying how their value (co-)varies with respect to the designated v variable.

(For scope, our system parallels Brasoveanu and Farkas (2011)'s treatment), see also Schlenker 2006).

Application I: Exceptional Scope of Indefinites

Indefinites violate rules of standard quantifier behaviour, e.g, can escape syntactic islands (Reinhart 1979, Abush 1993, . . .)

(20) Every kid$_x$ ate every food$_z$ that a doctor$_y$ recommended.

a. WS $[\exists y/\forall x/\forall z]$: $\forall x \forall z \exists_s y(\phi \wedge dep(v, y))$

b. IS $[\forall x/\exists y/\forall z]$: $\forall x \forall z \exists_s y(\phi \wedge dep(vx, y))$

c. NS $[\forall x/\forall z/\exists y]$: $\forall x \forall z \exists_s y(\phi \wedge dep(vxz, y))$

v	x	z	y
v_1	...	...	b_1
v_1	...	...	b_1
v_1	...	...	b_1
v_1	...	...	b_1

WS: $dep(v, y)$

v	x	z	y
v_1	a_1	...	b_1
v_1	a_1	...	b_1
v_1	a_2	...	b_2
v_1	a_2	...	b_2

IS: $dep(vx, y)$

v	x	z	y
v_1	a_1	c_1	b_1
v_1	a_1	c_2	b_2
v_1	a_2	c_3	b_3
v_1	a_2	c_4	b_4

NS: $dep(vxz, y)$

Indefinites interpreted *in-situ*. Exceptional scope behaviour captured using dependence atoms.

Application II: Specific Known, Specific Unknown, Non-specific

constancy ↦ known	$dep(\varnothing, x)$	$\begin{array}{cc} v & x \\ \hline \ldots & d_1 \\ \hline \ldots & d_1 \end{array}$
variation ↦ unknown	$var(\varnothing, x)$	$\begin{array}{cc} v & x \\ \hline \ldots & d_1 \\ \hline \ldots & d_2 \end{array}$

v-constancy ↦ specific	$dep(v, x)$	$\begin{array}{cc} v & x \\ \hline v_1 & d_1 \\ \hline v_2 & d_2 \end{array}$
v-variation ↦ non-specific	$var(v, x)$	$\begin{array}{cc} v & x \\ \hline v_1 & d_1 \\ \hline v_1 & d_2 \end{array}$

Scopal (specific vs non-specific) & epistemic (known vs unknown) distinctions

Specific Known:
constancy $dep(\varnothing, x)$

v	...	x
v_1	...	d_1
v_2	...	d_1

Application II: Specific Known, Specific Unknown, Non-specific

constancy $\mapsto$ known	$dep(\varnothing, x)$	v	x
		$\dots$	d_1
		$\dots$	d_1
variation $\mapsto$ unknown	$var(\varnothing, x)$	v	x
		$\dots$	d_1
		$\dots$	d_2

v-constancy $\mapsto$ specific	$dep(v, x)$	v	x
		v_1	d_1
		v_2	d_2
v-variation $\mapsto$ non-specific	$var(v, x)$	v	x
		v_1	d_1
		v_1	d_2

Specific Unknown:
v-constancy $dep(v, x)$ + variation $var(\varnothing, x)$

v	$\dots$	x
v_1	$\dots$	d_1
v_2	$\dots$	d_2

Application II: Specific Known, Specific Unknown, Non-specific

constancy $\mapsto$ known	$dep(\varnothing, x)$	$\begin{array}{cc} v & x \\ \hline \ldots & d_1 \\ \hline \ldots & d_1 \end{array}$
variation $\mapsto$ unknown	$var(\varnothing, x)$	$\begin{array}{cc} v & x \\ \hline \ldots & d_1 \\ \hline \ldots & d_2 \end{array}$

v-constancy $\mapsto$ specific	$dep(v, x)$	$\begin{array}{cc} v & x \\ \hline v_1 & d_1 \\ \hline v_2 & d_2 \end{array}$
v-variation $\mapsto$ non-specific	$var(v, x)$	$\begin{array}{cc} v & x \\ \hline v_1 & d_1 \\ \hline v_1 & d_2 \end{array}$

Non-specific:
v-variation $var(v, x)$

v	...	x
v_1	...	d_1
v_1	...	d_2

Application III: Variety of Indefinites

TYPE	FUNCTIONS SK	SU	NS	REQUIREMENT	EXAMPLE
(i) unmarked	✓	✓	✓	none	Italian *qualcuno*
(ii) specific	✓	✓	✗	$dep(v, x)$	Georgian *-ghats*
(iii) non-specific	✗	✗	✓	$var(v, x)$	Russian *-nibud*
(iv) epistemic	✗	✓	✓	$var(\varnothing, x)$	German *-irgend*
(v) specific known	✓	✗	✗	$dep(\varnothing, x)$	Russian *-koe*
(vi) SK + NS	✓	✗	✓	$dep(\varnothing, x) \mathbin{\rlap{\,/}\vee} var(v, x)$	unattested
(vii) specific unknown	✗	✓	✗	$dep(v, x) \wedge var(\varnothing, x)$	Kannada *-oo*

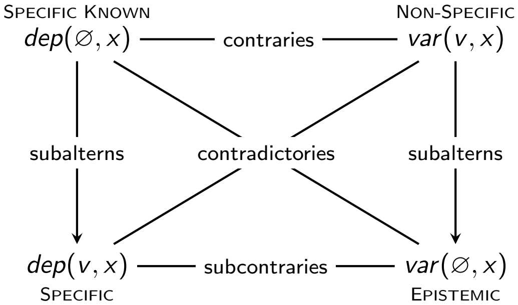
Why (ii)-(v) common? Why (vi) unattested? Why (vii) rare?

<u>common</u>
(ii)-(v): $\mapsto$ DEPENDENCE SQUARE OF OPPOSITION

<u>unattested</u>
(vi) SK + NS: violation of convexity (Gardenfors 2014)

<u>rare</u>
(vii) specific unknown: increased complexity

Application III: Dependence Square of Opposition



Dependence Square of Opposition

- Contraries: can be both false, but not both true.
- Contradictories: cannot be both true and they cannot be both false.
- Subcontraries: they cannot both be false but can both be true.
- Subalternation: *A* subalternates *B* iff *A* implies *B*.

Application III: Violation of convexity

- Convexity often assumed as a constraint on concept formation and lexicalization [Gardenfors 2014; Enguehard and Chemla 2021]
- Example: color space
  - A space is convex just in case for every two points contained therein, the line connecting them lies entirely within the space.
  - Color words (*blue, white, red, dots*) denote convex areas in color space
  - *Blue or white* and *not red* instead do not denote convex areas $\mapsto$ not natural concepts, not lexicalized
- Convexity without conceptual space: we need a relevant ordering
  - A meaning X is convex iff given $A < B < C$ and A in X and C in X then also B in X
- Indefinite functions SK, SU, NS $\mapsto$ sentential meanings
- In classical semantic theory, sentential meanings are sets of possible worlds. Unclear how worlds should be ordered.
- In team semantics: sentential meanings $\mapsto$ sets of teams.

$$[\phi]_M = \{T \mid M, T \models \phi\}$$

We can use $\subseteq$ as relevant ordering for defining convexity

Application III: Violation of convexity

- **Convex sets of teams**:
  - A set of teams P is convex iff for all T_1, T_2, T_3 such that $T_1 \subseteq T_2 \subseteq T_3$, if $T_1 \in P$ and $T_3 \in P$, then $T_2 \in P$.
- The Boolean union of the formulas associated with the SK and NS cells in our map does not satisfy convexity:
  - SK + NS: $dep(\varnothing, x) \vee\!\!\!/\, var(v, x)$ **[not convex]**
- The other two combinations instead define convex sets:
  - SK + SU: $dep(\varnothing, x) \vee\!\!\!/\, (var(\varnothing, x) \wedge dep(v, x)) \equiv dep(v, x)$ [convex]
  - SU + NS: $(var(\varnothing, x) \wedge dep(v, x)) \vee\!\!\!/\, var(v, x) \equiv var(\varnothing, x)$ [convex]
- A reasonable constraint on implicational maps: contiguous cells must denote convex properties (no gaps allowed!)
- This gives us a principled explanation of the specific ordering among functions assumed in the original Haspelmath's map:

SK-SU-NS	yes
SU-SK-NS	no
SK-NS-SU	no

Application IV: Licensing of non-specific indefinites

Non-specific indefinites are **ungrammatical in episodic sentences** and they need an operator (e.g. a universal quantifier, a modal or an attitude verb) which licenses them:

(21)* *Ivan včera kupil kakuju-nibud' knigu.*
Ivan yesterday bought which-INDEF. book.

'Ivan bought some book [non-specific] yesterday.'

(22) *Ivan* **hotel** *spet' kakuju-nibud' pesniu.*
Ivan want-PAST sing-INF some-nibud song.

'Ivan wanted to sing some song [non-specific].'

Application IV: Licensing of non-specific indefinites

Recall that non-specific indefinites are strict existentials which trigger v-variation: $var(v, x)$.

$$\exists_s x \ (\phi \wedge var(v, x))$$

v
v_1
v_2

Application IV: Licensing of non-specific indefinites

Recall that non-specific indefinites are strict existentials which trigger *v*-variation: $var(v, x)$.

$$\exists_s x \ (\phi \wedge var(v, x))$$

v
v_1
v_2

v	x
v_1	a_1
v_2	a_2

$var(v, x)$ cannot be satisfied!

No initial team can support $\exists_s x \ (\phi \wedge var(v, x))$

$\Rightarrow$ Non-specific indefinites predicted to be infelicitous in episodic sentences

Application IV: Licensing of non-specific indefinites

Recall that non-specific indefinites are strict existentials which trigger v-variation: $var(v, x)$.

$$\forall y \exists_s x \; (\phi \wedge var(v, x))$$

v
v_1
v_2

v	y
v_1	b_1
	b_2
v_2	b_1
	b_2

Application IV: Licensing of non-specific indefinites

Recall that non-specific indefinites are strict existentials which trigger v-variation: $var(v, x)$.

$$\forall y \exists_s x \; (\phi \wedge var(v, x))$$

v
v_1
v_2

v	y
v_1	b_1
	b_2
v_2	b_1
	b_2

v	y	x
v_1	b_1	a_1
	b_2	a_2
v_2	b_1	a_1
	b_2	a_2

$var(v, x)$ satisfied!

Initial teams can support $\forall y \exists_s x \; (\phi \wedge var(v, x))$

$\Rightarrow$ Non-specific indefinites predicted to be felicitous in universally quantified sentences

Application IV: Licensing of non-specific indefinites

Non-specific indefinites can also be licensed by modals or attitude verbs:

(23)* *On kupil kakoj-nibud' tort.*

On	*kupil*	*kakoj-nibud'*	*tort.*
He	buy-PAST	some-nibud	cake.

'He bought a cake.'

(24) *Ivan* **hotel** *spet' kakuju-nibud' pesniu.*

Ivan	**hotel**	*spet'*	*kakuju-nibud'*	*pesniu.*
Ivan	want-PAST	sing-INF	some-nibud	song.

'Ivan wanted to sing some song [non-specific].'

(25) *On* **mog** *kupit' kakoj-nibud' tort.*

On	**mog**	*kupit'*	*kakoj-nibud'*	*tort.*
He	can-PAST	buy-INF	some-nibud	cake

'He could buy a cake.'

Application IV: Licensing of non-specific indefinites

Basic Idea:

Modals as **lax quantifiers** over worlds: $\Box_w \sim \forall w$ and $\Diamond_w \sim \exists_{l(ax)} w$

(26) Necessity Modal

a. You must take some-*nibud* book

b. $\forall w \exists_s x(\phi(x, w) \wedge var(v, x))$

(27) Possibility Modal

a. You may take some-*nibud* book

b. $\exists_l w \exists_s x(\phi(x, w) \wedge var(v, x))$

Application IV: Licensing of non-specific indefinites

We obtain the correct licensing behaviour!

$$\exists_l w \exists_s x(\phi(x,w) \wedge var(v,x))$$

v
v_1
v_2

v	w
v_1	w_1
	w_2
v_2	w_1

v	w	x
v_1	w_1	a_1
	w_2	a_2
v_2	w_1	a_1

$var(v,x)$ satisfied!

Initial teams can support $\exists_l w \exists_s x(\phi(x,w) \wedge var(v,x))$

$\Rightarrow$ Non-specific indefinites predicted to be felicitous under (possibility) modals (but not under other indefinites (strict existential))

Aside: Epistemic Modals via Inclusion Atoms

(28) **Epistemic** vs **Deontic**

a. Aicha might be in Paris.

b. Aicha is allowed to go to Paris.

Only epistemic modals give rise to **epistemic contradictions**:

(29) # Aicha might be in Paris and she is not in Paris.

Epistemic modals quantify over epistemic possibilities of the speaker (encoded by v in our system).

Deontic modals interpreted wrt 'normative' rules, not necessarily compatible with the state of affairs in the actual world.

Aside: Epistemic Modals via Inclusion Atoms

Proposal: epistemic modals as inclusion atoms triggers

(30) a. Aicha might be in Paris.

b. $\exists_I w\ (P(a, w) \wedge w \subseteq v)$

Inclusion Atom:

$$M, T \models \vec{x} \subseteq \vec{y} \Leftrightarrow \text{ for all } i \in T, \text{ there is a } j \in T : i(\vec{x}) = j(\vec{y})$$

x	y	z
d_1	d_1	d_2
d_1	d_2	d_2
d_2	d_3	d_4
d_2	d_4	d_4

$x \subseteq y$ ✓
$xz \subseteq xy$ ✓
$y \subseteq x$ ✗

General picture

Indefinites: strict existentials over individual variables
differences captured via ⇒ Dependence and Variation Atoms
Modals: lax quantifiers over world variables
differences captured via ⇒ Inclusion Atoms

Aside: Epistemic Modals via Inclusion Atoms

(31) Epistemic

a. # Aicha might be in Paris and she is not in Paris.

b. $\exists_I w\ (P(a,w) \wedge w \subseteq v) \wedge \neg P(a,v) \models \bot$

(32) Deontic

a. Aicha is allowed to be in Paris and she is not in Paris.

b. $\exists_I w\ (P(a,w) \wedge R(v,w)) \wedge \neg P(a,v) \not\models \bot$

v
v_1
v_2
v_3

v	w
v_1	v_1
v_1	v_2
v_2	v_1
v_2	v_2
v_3	v_1
v_3	v_2

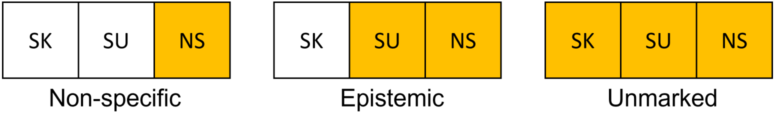
Epistemic

v	w
v_1	w_1
v_1	w_2
v_2	w_1
v_2	w_2
v_3	w_1
v_3	w_2

Deontic

Application V: From non-specific to epistemic

Frequent diachronic tendency: **non-specific** > **epistemic** (e.g. French *quelque* (Foulet 1919) and German *irgendein* (Port and Aloni 2015))



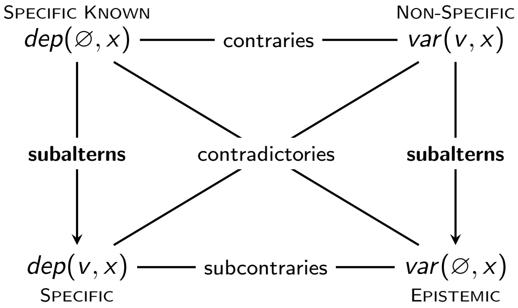
Haspelmath (1997)'s explanation: weakening of functions from the right (non-specific) of the functional map to the left (specific).

(33) **Weakening of functions (a)** > **(b)** > **(c)**
(a) non-specific
(b) non-specific + specific unknown = epistemic
(c) epistemic + specific known = unmarked

But then why diachronically we do not observe the change from (b) to (c)?

Application V: Dependence Square of Opposition

Our framework makes the notion of weakening precise in terms of **subalternation** in our square of opposition



By subalternation we predict the following possible diachronic developments:

(i) NON-SPECIFIC > EPISTEMIC (attested)

(ii) SPECIFIC KNOWN > SPECIFIC (conjectured)

But (ii) might violate another constraint on language change

Application V: concrete > abstract

- The representation of **known vs unknown** requires variables ranging over W, a domain of abstract entities
  - Without world variables: Specific ($dep(\emptyset, x)$) vs Non-specific ($var(\emptyset, x)$)
  - With world variables: Dependence Square of Opposition
- It is reasonable to conjecture that individual quantification precedes world quantification

  concrete > abstract

- This conjecture gives rise to different predictions concerning diachronic tendencies:

  (i) NON-SPECIFIC > EPISTEMIC (attested)

  (ii) SPECIFIC > SPECIFIC KNOWN (conjectured)

- Possibly both factors (weakening and concreteness) play a role explaining why only (i) is frequently attested

	weakening	**concreteness**
NON-SPECIFIC > EPISTEMIC	yes	yes
SPECIFIC > SPECIFIC KNOWN	no	yes
SPECIFIC KNOWN > SPECIFIC	yes	no
EPISTEMIC > SPECIFIC KNOWN	no	=

Final Proposal

We propose that:

1. Indefinites are **strict existentials**;
2. They are interpreted **in-situ**;
3. An unmarked/plain indefinite $\exists_s x$ in **syntactic scope** of $O_{\vec{z}}$ allows all $dep(\vec{y}, x)$, with $\vec{y}$ included in $v\vec{z}$:

$$O_{z_1} \ldots O_{z_n} \exists_s x(\phi \wedge dep(\vec{y}, x))$$

4. **Marked indefinites** additionally trigger the obligatory activation of particular dependence or variation atoms.

Final Proposal

$$O_{z_1} \dots O_{z_n} \exists_s x(\phi \wedge \dots)$$

Unmarked: $dep(\vec{y}, x)$, where $\vec{y} \subseteq v\vec{z}$

Specific known: $dep(\vec{y}, x)$ with $\vec{y} = \varnothing$

Specific: $dep(\vec{y}, x)$ with $\vec{y} = v$

Epistemic: $dep(\vec{y}, x) \wedge var(\vec{z}, x)$ with $\vec{z} = \varnothing$

Non-specific: $dep(\vec{y}, x) \wedge var(\vec{z}, x)$ with $\vec{z} = v$

Specific unknown: $dep(\vec{y}, x) \wedge var(\vec{z}, x)$ with $\vec{y} = v$ and $\vec{z} = \varnothing$

Application VI: Interaction with Scope

$$\forall z \forall y \exists_s x \; \phi$$

	WS-K $dep(\varnothing, x)$	WS $dep(v, x)$	IS $dep(vy, x)$	NS $dep(vyz, x)$
unmarked	✓	✓	✓	✓
specific $dep(v, x)$	✓	✓	✗	✗
non-specific $var(v, x)$	✗	✗	✓	✓
epistemic $var(\varnothing, x)$	✗	✓	✓	✓
specific known $dep(\varnothing, x)$	✓	✗	✗	✗
specific unknown $dep(v, x) \wedge var(\varnothing, x)$	✗	✓	✗	✗

Note that non-specific indefinites also allow intermediate readings (Partee 2004):

(34) *Možet byt', Maša xočet kupit' kakuju-nibud' knigu.*
may be, Maša want buy which-INDEF. book.

a. Narrow Scope: It may be that Maša wants to buy some book.

b. Intermediate Scope: It may be that there is some book which Maša wants to buy.

c. #Wide-scope: There is some book such that it may be that Maša wants to buy it.

Negation and Implication

Negation so far can only be defined for the classical fragment of the language (including identity[1]).

To express natural language negation we can adopt an intensional notion, along the lines of Brasoveanu and Farkas (2011).

(35) **Intensional Negation**

$$\neg\phi \Leftrightarrow \forall w(\phi[v/w] \rightarrow v \neq w)$$

(36) **Clause for Implication**

$M, X \models \phi \rightarrow \psi \Leftrightarrow$ for **some** $X' \subseteq X$ s.t. $M, X' \models \phi$ and X' is maximal (i.e. for all X'' s.t. $X' \subset X'' \subseteq X$, $M, X'' \not\models \phi$), we have $M, X' \models \psi$

1

$$M, T \models x \neq y \Leftrightarrow \forall i \in T : i(x) \neq i(y)$$

Negation and Epistemic Indefinites

Desideratum: EIs under negation display an NPI behaviour (e.g., *any*).

EIs under negation as in (37) are supported when the initial team contains just $\{w_\varnothing\}$. (In $w_\varnothing$ John read no book, in w_a John read only book a, and so on.)

(37) a. John does not have *irgend*-book.

b. $\forall w(\exists_s x(\phi(x,w) \wedge dep(vw,x) \wedge var(\varnothing,x)) \rightarrow \mathbf{v} \neq \mathbf{w})$

v	w	x
$w_\varnothing$	$w_\varnothing$	—
$w_\varnothing$	w_a	a
$w_\varnothing$	w_b	b
$w_\varnothing$	w_{ab}	b

v	w	x
w_a	$w_\varnothing$	—
$\mathbf{w_a}$	$\mathbf{w_a}$	$\mathbf{a}$
w_a	w_b	b
w_a	w_{ab}	a

[maximal teams supporting antecedent in blue; in red assignments violating consequent]

Negation and Specific Indefinites

Does the *some*/*all* distinction matters in the semantic clause for maximal implication?

For union-closed formulas, it does not. The difference is trivialized.

But not all formulas in our language are union-closed!

Let's consider what happens in the case of specific (known) indefinites.

(38) a. John does not have some-SK book.

b. $\forall w(\exists_s x(\phi(x, w) \wedge dep(\varnothing, x)) \rightarrow v \neq w)$

As in (38), specific indefinites under negation are supported by $\{w_\varnothing\}$ (John has no book), and also by $\{w_a\}$ (John has book *a* and not *b*) or $\{w_b\}$. But not by $\{w_{ab}\}$ (John has all books).

Supporting and Non-Supporting Teams

(39) a. John does not have some-SK book.

b. $\forall w(\exists_s x(\phi(x,w) \wedge dep(\varnothing, x)) \rightarrow v \neq w)$

v	w	x
$w_\varnothing$	$w_\varnothing$	a
$w_\varnothing$	w_a	a
$w_\varnothing$	w_b	a
$w_\varnothing$	w_{ab}	a

v	w	x
$w_\varnothing$	$w_\varnothing$	b
$w_\varnothing$	w_a	b
$w_\varnothing$	w_b	b
$w_\varnothing$	w_{ab}	b

v	w	x
w_a	$w_\varnothing$	a
$\mathbf{w_a}$	$\mathbf{w_a}$	a
w_a	w_b	a
w_a	w_{ab}	a

v	w	x
w_a	$w_\varnothing$	b
w_a	w_a	b
w_a	w_b	b
w_a	w_{ab}	b

v	w	x
w_{ab}	$w_\varnothing$	a
w_{ab}	w_a	a
w_{ab}	w_b	a
$\mathbf{w_{ab}}$	$\mathbf{w_{ab}}$	**a**

v	w	x
w_{ab}	$w_\varnothing$	b
w_{ab}	w_a	b
w_{ab}	w_b	b
$\mathbf{w_{ab}}$	$\mathbf{w_{ab}}$	**b**

[only for $\{w_{ab}\}$ no maximal team supporting the antecedent also supports the consequent, therefore $\{w_\varnothing\}$, $\{w_a\}$ support (39b) but $\{w_{ab}\}$ doesn't.]

Conclusion

We have developed a **two-sorted team semantics** framework accounting for indefinites cross-linguistically.

In this framework, **marked indefinites** trigger the obligatoriness of dependence or variation atoms, responsible for their scopal and epistemic interpretations.

We have applied the framework to characterize the **typological variety of indefinites** in the case of (non-)specificity.

We have then showed how this system can be used to explain several **properties and phenomena** associated with (non-)specific indefinites.

THANK YOU![2]

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