Disjunction in state-based semantics

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Introduction

- State-based semantics (broadly conceived): formulas are interpreted wrt states rather than possible worlds
- States: less determinate entities than worlds, can be
  - truthmakers, possibilities, situations, information states and more
- Here: states = sets of possible worlds

Three disjunctions in state-based semantics

1. Possibility/dynamic semantics: $\vee_1$
2. Team/assertability logic: $\vee_2$
3. Truthmaker/inquisitive semantics: $\vee_3$

Goals of today

- Compare these notions with emphasis on their potential to account for Free Choice (FC) inferences:
  - Wide scope FC: $\Diamond a \vee \Diamond b \rightsquigarrow \Diamond a \wedge \Diamond b$
  - Narrow scope FC: $\Diamond(a \vee b) \rightsquigarrow \Diamond a \wedge \Diamond b$
- Present a new state-based system:
  - System B: a logical account of narrow & wide scope FC using an enriched version of $\vee_2$ + "classical" $\Diamond$

The paradox of free choice

- Free choice permission in natural language:

(1) You may (A or B) $\rightsquigarrow$ You may A

- But (2) not valid in standard deontic logic (von Wright 1968):

(2) $\Diamond(\alpha \vee \beta) \to \Diamond\alpha$ [Free Choice Principle]

- Plainly making the Free Choice Principle valid, for example by adding it as an axiom, would not do (Kamp 1973):

(3)
1. $\Diamond a$ [assumption]
2. $\Diamond(a \vee b)$ [from 1, by modal addition]
3. $\Diamond b$ [from 2, by free choice principle]

- The step leading to 2 in (3) uses the following valid principle:

(4) $\Diamond\alpha \to \Diamond(\alpha \vee \beta)$ [Modal Addition]

- Natural language counterpart of (4), however, seems invalid:

(5) You may A $\not\rightsquigarrow$ You may (A or B)

⇒ Intuitions on natural language in direct opposition to the principles of deontic logic

Reactions to paradox

- Paradox of Free Choice Permission (with extension to wide scope FC)

(6) 1. $\Diamond a$ [assumption]
2. $\Diamond(a \vee b)$ / $\Diamond a \vee \Diamond b$ [from 1, by (modal) addition]
3. $\Diamond b$ [from 2, by wide/narrow scope FC principle]

- Pragmatic solutions: FC as implicature; step leading to 3 unjustified
- Semantic solutions: FC as entailment; step leading to 3 justified, but step leading to 2 no longer valid
- Today: a "semantic" account $\mapsto$ addition no longer valid
- Free choice: semantics or pragmatics?
  - Arguments for/against semantic and pragmatic approaches are often inconclusive
- My view:
  - FC inferences: neither purely semantic nor purely pragmatic, rather inferences of the third kind
  - Derivable by conversational principles but lacking other defining properties of pragmatic inferences: non-cancellable, embeddable (FC indefinites), equal to literal meaning ito processing time, . . .

Free choice: semantics or pragmatics?

Argument in favour of pragmatic account of FC disjunction

- Free choice effects systematically disappear in negative contexts:

(7) You are not allowed to eat the cake or the ice-cream.

a. $\equiv \neg\Diamond(a \vee b) \equiv \neg\Diamond a \wedge \neg\Diamond b$

b. $\not\equiv \neg(\Diamond a \wedge \Diamond b)$

(7) never means (7-b), as would be expected if free choice effects were semantic entailments rather than pragmatic implicatures (Alonso-Ovalle 2005)

Is this argument really conclusive?

- Our "semantic" system will account for the facts in (7);
- Any pragmatic system which predicts the availability of embedded FC implicatures (Chierchia, Fox) needs adjustments to account for these facts.

State-based semantics

- In a state-based semantics formulas are interpreted wrt states (here sets of possible worlds) rather than possible worlds

Language

$$\phi \quad := \quad p \mid \neg\phi \mid \phi \wedge \phi \mid \phi \vee \phi \mid \Diamond\phi$$

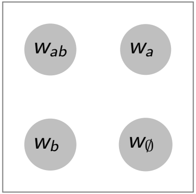
where $p \in A$.

Models and States

- Standard Kripke models $M = \langle W, R, V \rangle$
- A state s is a set of possible worlds in W

Logical space

for $A = \{a, b\}$



Basic semantic clauses

$$\begin{array}{rcl} s \models p & \text{iff} & \forall w \in s : V(w,p) = 1 \\ s \models \phi \wedge \psi & \text{iff} & s \models \phi \ \& \ s \models \psi \\ s \models \neg\phi & \text{iff} & \forall w \in s : \{w\} \not\models \phi \end{array}$$

Logical consequence

- $\phi \models \psi$ iff $\forall M, s : M, s \models \phi \;\Rightarrow\; M, s \models \psi$

Distributivity

- ϕ is distributive, if $\forall M, s : M, s \models \phi \Leftrightarrow \forall w \in s : M, \{w\} \models \phi$

Facts

- p, $\neg\phi$ are distributive;
- $\emptyset \models \phi$, if ϕ is distributive;
- So far consequence relation is classical (Humberstone 1981);
- But bivalence fails, e.g. for $s = \{w_a, w_b\}$: $s \not\models a \;\; \& \;\; s \not\models \neg a$.

Three notions of disjunction

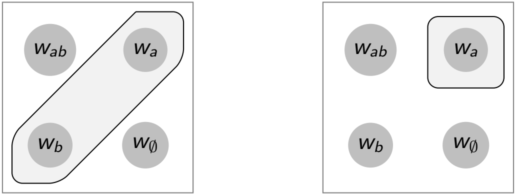
$s \models \phi \vee_1 \psi$	iff	$\forall w \in s : \{w\} \models \phi$ or $\{w\} \models \psi$	(possibility/dynamics)
$s \models \phi \vee_2 \psi$	iff	$\exists t, t' : t \cup t' = s \;\&\; t \models \phi \;\&\; t' \models \psi$	(team/assertability logic)
$s \models \phi \vee_3 \psi$	iff	$s \models \phi$ or $s \models \psi$	(inquisitive/truthmaker semantics)

Facts

1. $\phi \vee_1 \psi \equiv \neg(\neg\phi \wedge \neg\psi)$
2. $\models \phi \vee_{1/2} \neg\phi$, but $\not\models \phi \vee_3 \neg\phi$

If ϕ, ψ are distributive,

3. $\phi \vee_1 \psi \equiv \phi \vee_2 \psi$
4. $\phi \vee_3 \psi \models \phi \vee_{1/2} \psi$, but $\phi \vee_{1/2} \psi \not\models \phi \vee_3 \psi$



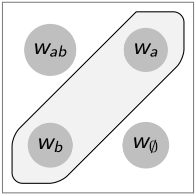
(a) $\models (a \vee_{1/2/*3} b)$ (b) $\models (a \vee_{1/2/3} b)$

Three notions of disjunction

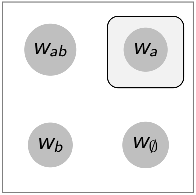
$s \models \phi \vee_1 \psi$	iff	$\forall w \in s : \{w\} \models \phi$ or $\{w\} \models \psi$	(possibility/dynamics)
$s \models \phi \vee_2 \psi$	iff	$\exists t, t' : t \cup t' = s \;\&\; t \models \phi \;\&\; t' \models \psi$	(team/assertability logic)
$s \models \phi \vee_3 \psi$	iff	$s \models \phi$ or $s \models \psi$	(inquisitive/truthmaker semantics)

Different conceptualisations for different notions of disjunction

- $\vee_{1/2}$ makes sense if $s \models \phi$ reads as
  - "agent in state s has enough evidence to assert ϕ" (assertability)
- $\vee_3$ makes sense if $s \models \phi$ reads as
  - "ϕ is true because of fact s" (truthmaker semantics)
  - "s contains enough information to resolve ϕ" (inquisitive semantics)



(c) $\not\models (a \vee_3 b)$



(d) $\models (a \vee_3 b)$

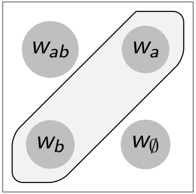
Three notions of disjunction

$s \models \phi \vee_1 \psi$	iff	$\forall w \in s : \{w\} \models \phi$ or $\{w\} \models \psi$	(possibility/dynamics)
$s \models \phi \vee_2 \psi$	iff	$\exists t, t' : t \cup t' = s \;\&\; t \models \phi \;\&\; t' \models \psi$	(team/assertability logic)
$s \models \phi \vee_3 \psi$	iff	$s \models \phi$ or $s \models \psi$	(inquisitive/truthmaker semantics)

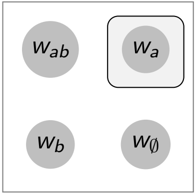
Disjunction and indeterminacy

(8) A: *X* or *Y* will win the election (Grice 1991, p 82)
B: No, *X* or *Y* or *Z* will win the election.

- $\vee_{1/2}$ allow a direct account of indeterminacy of disjunction
- $\vee_3$ needs extra machinery: modal operators (Data Semantics) or shift to set of states (Inquisitive Semantics)



(e) $\not\models (a \vee_3 b)$



(f) $\models (a \vee_3 b)$

Three notions of disjunction

$s \models \phi \vee_1 \psi$ iff $\forall w \in s : \{w\} \models \phi$ or $\{w\} \models \psi$ (possibility/dynamics)

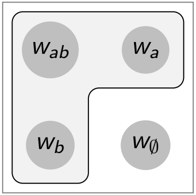
$s \models \phi \vee_2 \psi$ iff $\exists t, t' : t \cup t' = s \;\&\; t \models \phi \;\&\; t' \models \psi$ (team/assertability logic)

$s \models \phi \vee_3 \psi$ iff $s \models \phi$ or $s \models \psi$ (inquisitive/truthmaker semantics)

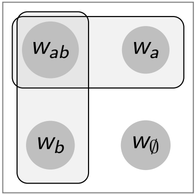
Different semantic contents generated by different notions

Let ϕ, ψ be distributive and logically independent.

1. $\{s \mid s \models (\phi \vee_3 \psi)\}$ is inquisitive, i.e. it contains more than one maximal state, aka alternative;
2. $\{s \mid s \models (\phi \vee_{1/2} \psi)\}$ is not inquisitive.



(g) classical: $a \vee_{1/2} b$



(h) inquisitive: $a \vee_3 b$

- Alternatives generated by $\vee_3$ largely used in semantics

Exact vs inexact

- In all versions if $\phi \models \psi$ then $\psi \vee \phi \equiv \psi$, in particular:
  - $a \equiv a \vee_i (a \wedge b)$ $\quad i \in \{1, 2, 3\}$
- In contrast to Fine's exact truthmaker semantics

A linguistic argument for inexact semantics (Ciardelli et al)

- One wants to distinguish between good and bad disjunctions:

(9) #John is an American or a Californian.

(10) Alice came or Bob or both.

- Best strategy: adopt an inexact semantics complemented with (i) a ban against redundancy; (ii) an optional, but constrained EXH
- In inexact semantics: both (9) and (10) redundant because $\phi \models \psi$ and $\psi \vee \phi \equiv \psi$
- But (10) (and not (9)) can be crucially rescued by an application of EXH on the weak disjuncts that breaks the entailment:

(11) EXH(Alice came) = Alice came and Bob did not come ...

(12) EXH(John is an American) $\neq$ John is an American and not a Californian, ...

Three notions of modality

$s \models \Diamond_1\phi$	iff	$\forall w \in s : \exists t \subseteq R^{\rightarrow}(w) : t \neq \emptyset \ \& \ t \models \phi$	("classical")
$s \models \Diamond_2\phi$	iff	$s \not\models \neg\phi$	(state-based)
$s \models \Diamond_3\phi$	iff	$\forall w \in s : \forall t \in alt(\phi) : R^{\rightarrow}(w) \cap t \neq \emptyset$	(alternative-sensitive)

Auxiliary notions: $R^{\rightarrow}(w) = \{v \mid wRv\}$;
$alt(\phi) = \{s \mid s \models \phi \ \& \ \neg\exists s' : s' \models \phi \ \& \ s \subset s'\}$.

1. $\Diamond_1$ is a "classical" modal operator interpreted wrt a relational structure (Humberstone 1981);
2. $\Diamond_2$ proposed for epistemic modals (Veltman, Hawke & Steinert-Threlkeld):

   (13) #It might be raining but it is not raining.

   - Epistemic contradiction: $\Diamond_2\phi \wedge \neg\phi \models \bot$ (Yalcin 2007)
   - Non-factivity: $\Diamond_2\phi \not\models \phi$
3. $\Diamond_3$ motivated by FC phenomena (Aloni 2007, Ciardelli & Aloni 2013/16):
   - If ϕ is inquisitive, it generates free choice effects. Otherwise, $\Diamond_3$ behaves classically:
   - No modal contradiction: $\Diamond_3\phi \wedge \neg\phi \not\models \bot$
   - Non-factivity: $\Diamond_3\phi \not\models \phi$
   - ...

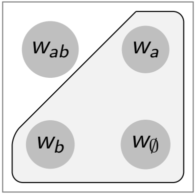
Some facts

Facts concerning distributivity

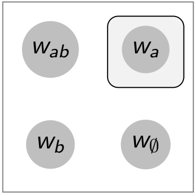
- Classical $\Diamond_1 \phi$ and alternative-sensitive $\Diamond_3 \phi$ are distributive
- State-based $\Diamond_2 \phi$ is non-distributive

Facts concerning disjunction

- If ϕ, ψ are distributive, $\phi \vee_1 \psi \equiv \phi \vee_2 \psi$; $\phi \vee_3 \psi \models \phi \vee_{1/2} \psi$
- $\phi \vee_2 \psi \not\models \phi \vee_1 \psi$
  Counterexample: $[w_a, w_\emptyset, w_b] \models \Diamond_2 a \vee_2 \Diamond_2 b$, but $[w_a, w_\emptyset, w_b] \not\models \Diamond_2 a \vee_1 \Diamond_2 b$
- $\phi \vee_{1/3} \psi \not\models \phi \vee_2 \psi$
  Counterexample: $[w_a] \models \Diamond_2 a \vee_{1/3} \Diamond_2 b$, but $[w_a] \not\models \Diamond_2 a \vee_2 \Diamond_2 b$



(i) $\not\models \Diamond_2 a \vee_1 \Diamond_2 b$



(j) $\not\models \Diamond_2 a \vee_2 \Diamond_2 b$

Facts about free choice

- $\vee_1$ and $\Diamond_1$ generate classical modal logic (no free choice effects)
- Assertability $\vee_2$ with state-based $\Diamond_2$ gives us wide scope FC (Hawke & Steinert-Threlkeld 2016):

$$\Diamond_2 a \vee_2 \Diamond_2 b \models \Diamond_2 a \wedge \Diamond_2 b$$
$$\Diamond_2 (a \vee_2 b) \not\models \Diamond_2 a \wedge \Diamond_2 b$$

- Inquisitive $\vee_3$ with alternative-sensitive $\Diamond_3$ gives us narrow scope FC inference (Aloni 2007, Ciardelli & Aloni 2013/16):

$$\Diamond_3 (a \vee_3 b) \models \Diamond_3 a \wedge \Diamond_3 b$$
$$\Diamond_3 a \vee_3 \Diamond_3 b \not\models \Diamond_3 a \wedge \Diamond_3 b$$

- But problems under negation:

$$\neg(\Diamond_2 a \vee_2 \Diamond_2 b) \not\models \neg\Diamond_2 a \wedge \neg\Diamond_2 b$$
$$\neg\Diamond_3 (a \vee_3 b) \not\models \neg\Diamond_3 a \wedge \neg\Diamond_3 b$$

Results so far

1. Classical $\vee_1 + \Diamond_1$: no FC inference
2. Assertability $\vee_2 + \Diamond_2$: only WS epistemic FC with negation problem
3. Inquisitive $\vee_3 + \Diamond_3$: only NS FC with negation problem

Desiderata

- An account of narrow scope (NS) and wide scope (WS) FC;
- For epistemic and other modals (notably, deontics);
- Well-behaving under negation.

Three strategies

- Strategy A: Extend 1 with a pragmatic account of FC;
  - would avoid the negation problem;
  - hard to pragmatically derive WS FC
- Strategy B: Extend 2 with an account of NS FC;
- Strategy C: Extend 3 with an account of WS FC
  - diverse strategies to solve negation problem;
  - but hard to derive WS FC for both epistemic and deontic modals.

Today

- System B: a "semantic" account of narrow and wide scope FC using an enriched version of $\vee_2$ in combination with $\Diamond_1$

Against reductionism

- Variety of FC accounts:
  - Wide reductionism: narrow scope FC reduced to wide scope FC
  - Narrow reductionism: wide scope FC reduced narrow scope FC
- **Problem for wide reductionism**: scalar implicature of (14) can only be derived from a narrow-scope structure (Fox 2007):

(14) Mary may have ice-cream or cake. (+fc, narrow-scope)

a. logical form: $\Diamond(a \vee b)$ / $\#\Diamond a \vee \Diamond b$

b. free choice inference : $\Diamond a \wedge \Diamond b$

c. scalar implicature: $\neg\Diamond(a \wedge b)$

- **Problem for narrow reductionism**: narrow scope LF for (15) would require dubious syntactic operations (Alonso-Ovalle 2006):

(15) You may email us or you can reach the Business License office at 949 644-3141. (+fc, wide-scope)

a. logical form: $\Diamond a \vee \Diamond b$ / $\#\Diamond(a \vee b)$

b. free choice inference : $\Diamond a \wedge \Diamond b$

c. no scalar implicature

System B: some linguistic evidence

Disjunction and uncertainty

- In languages lacking explicit *or*, disjunctive meaning expressed by adding a suffix/particle expressing uncertainty to the main verb:

(16) Johnš Billš v?aawuumšaa.
John-nom Bill-nom 3-come-pl-fut-infer
'John or Bill will come'

(17) Johnš Billš v?aawuum.
John-nom Bill-nom 3-come-pl-fut
'John and Bill will come' [Maricopa, Gil 1991, p. 102]

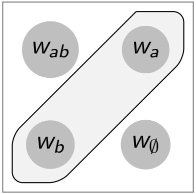
System B

- semantic contribution of *or* identified with precisely these epistemic effects
- plain disjunction taken to convey that both disjuncts are open options

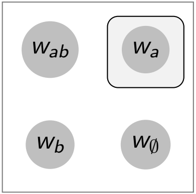
System B: semantic account of wide and narrow scope FC

Disjunction

- Adopt an enriched version of $\vee_2 \mapsto \vee_+$
- A state s supports a disjunction $(\phi \vee_+ \psi)$ iff s can be split into two non-empty substates, each supporting one of the disjuncts, e.g.



(k) $\models (a \vee_+ b)$



(l) $\not\models (a \vee_+ b)$

- $[w_a, w_b]$, $[w_{ab}]$ support $(a \vee_+ b)$;
- but $[w_a]$ no longer supports $(a \vee_+ b)$ [$\Leftarrow$ crucial for narrow scope FC]

System B: semantic account of wide and narrow scope FC

Negation facts

- To account for negation facts we adopt a bilateral system:
  - $s \vdash \phi$ interpreted as "ϕ is assertable in s";
  - $s \dashv \phi$ interpreted as "ϕ is rejectable in s".

Modality

- A "classical" notion of modality:

$$M, s \vdash \Diamond\phi \quad \text{iff} \quad \forall w \in s : \exists t \subseteq R^{\rightarrow}(w) : t \neq \emptyset \;\&\; t \vdash \phi$$

$$M, s \dashv \Diamond\phi \quad \text{iff} \quad \forall w \in s : \forall t \subseteq R^{\rightarrow}(w) : t \neq \emptyset \;\Rightarrow\; t \dashv \phi$$

- Deontic vs epistemic contrast captured in terms of properties of the accessibility relation
  - Epistemics: R is state-based
  - Deontics: R is possibly indisputable (e.g. in performative uses)

Outlook of results

- Narrow scope FC derived because relevant embedded state has to support an enriched disjunction
- Wide scope FC derived, if R indisputable [state-based $\Rightarrow$ indisput.]
- Epistemic contradiction derived, if R state-based [epistemics]

System B: definitions

Language

$$\phi \quad := \quad p \mid \neg\phi \mid \phi \wedge \phi \mid \phi \vee \phi \mid \Diamond\phi \mid \text{NE}$$

where $p \in A$.

Models

- $M = \langle s_M, W, R, V\rangle$, where s_M is a subset of W, W is a set of worlds, R is an accessibility relation and V is a world-dependent valuation function for A (s_M stands for speaker information state)

State-based constraints on accessibility relation

- R is indisputable in M iff $\forall w, v \in s_M : R^{\rightarrow}(w) = R^{\rightarrow}(v)$
  $\mapsto$ speaker is fully informed about R
- R is state-based in M iff $\forall w \in s_M : R^{\rightarrow}(w) = s_M$
  $\mapsto$ all and only worlds in s_M are accessible within s_M

where $R^{\rightarrow}(w) = \{v \mid wRv\}$

System B: semantic clauses

$[M = \langle s_M, W, R, V\rangle,\ s, t, t' \subseteq W]$

$$
\begin{array}{rcl}
M, s \vdash p & \text{iff} & \forall w \in s : V(w,p) = 1 \\
M, s \dashv p & \text{iff} & \forall w \in s : V(w,p) = 0 \\
M, s \vdash \neg\phi & \text{iff} & M, s \dashv \phi \\
M, s \dashv \neg\phi & \text{iff} & M, s \vdash \phi \\
M, s \vdash \phi \wedge \psi & \text{iff} & M, s \vdash \phi \ \&\ M, s \vdash \psi \\
M, s \dashv \phi \wedge \psi & \text{iff} & \exists t, t' : t \cup t' = s \ \&\ M, t \dashv \phi \ \&\ M, t' \dashv \psi \\
M, s \vdash \phi \vee \psi & \text{iff} & \exists t, t' : t \cup t' = s \ \&\ M, t \vdash \phi \ \&\ M, t' \vdash \psi \\
M, s \dashv \phi \vee \psi & \text{iff} & M, s \dashv \phi \ \&\ M, s \dashv \psi \\
M, s \vdash \Diamond\phi & \text{iff} & \forall w \in s : \exists t \subseteq R^{\rightarrow}(w) : t \neq \emptyset \ \&\ t \vdash \phi \\
M, s \dashv \Diamond\phi & \text{iff} & \forall w \in s : R^{\rightarrow}(w) \dashv \phi \\
M, s \vdash \mathrm{NE} & \text{iff} & s \neq \emptyset \\
M, s \dashv \mathrm{NE} & \text{iff} & s = \emptyset
\end{array}
$$

where $R^{\rightarrow}(w) = \{v \mid wRv\}$

System B: logical consequence and enriched disjunction

Logical consequence

- $\phi \models \psi$ iff $\forall M : M, s_M \vdash \phi \;\Rightarrow\; M, s_M \vdash \psi$

Enriched disjunction

- or $\mapsto \vee_+$
- $(\phi \vee_+ \psi) =: (\phi \wedge \text{NE}) \vee (\psi \wedge \text{NE})$

Bottom and necessity

- $\bot =: \neg\text{NE}$
- $\Box\phi =: \neg\Diamond\neg\phi$

System B: facts about modals

Epistemic contradiction

1. $\Diamond a \wedge \neg a \models \bot$ [if R is state-based]
2. $\Diamond a \not\models a$

Epistemics vs deontics

- Differ wrt properties of accessibility relation:
  - Epistemics: R is state-based
  - Deontics: R is possibly indisputable (e.g. in performative uses)
- Epistemic contradiction predicted for epistemics, but not for deontics:

(18) #It might be raining and it is not raining.

(19) You are not there but you may go there.

System B: facts about free choice

Narrow scope and wide scope FC

1. $\Diamond(a \vee_+ b) \models \Diamond a \wedge \Diamond b$
2. $\Diamond a \vee_+ \Diamond b \models \Diamond a \wedge \Diamond b$ [if R is indisputable]

FC effects also for plain disjunction and $\Box$

3. $a \vee_+ b \models \Diamond a \wedge \Diamond b$ [if R is state-based]
4. $\Box(a \vee_+ b) \models \Diamond a \wedge \Diamond b$ ($\Box \equiv \neg\Diamond\neg$)

FC effects disappear under negation

5. $\neg\Diamond(a \vee_+ b) \models \neg\Diamond a \wedge \neg\Diamond b$
6. $\neg(\Diamond a \vee_+ \Diamond b) \models \neg\Diamond a \wedge \neg\Diamond b$
7. $\neg(a \vee_+ b) \models \neg a \wedge \neg b$

System B: epistemic free choice

Narrow scope and wide scope FC

1. $\Diamond(a \vee_+ b) \models \Diamond a \wedge \Diamond b$
2. $\Diamond a \vee_+ \Diamond b \models \Diamond a \wedge \Diamond b$ [if R is indisputable]

Epistemic modals

- R is state-based, therefore always indisputable

(20) He might either be in London or in Paris. [+fc, narrow]

(21) He might be in London or he might be in Paris. [+fc, wide]

- $\Rightarrow$ narrow and wide scope FC always predicted for epistemics
- Potential problem: wide FC for epistemic modals appears to arise more strongly than narrow scope FC (Steinert-Threlkeld 2017)

System B: deontic free choice

Narrow scope and wide scope FC

1. $\Diamond(a \vee_+ b) \models \Diamond a \wedge \Diamond b$
2. $\Diamond a \vee_+ \Diamond b \models \Diamond a \wedge \Diamond b$ [if R is indisputable]

Deontic modals

- R indisputable if speaker is knowledgable (e.g. in performative uses)
  - $\Rightarrow$ narrow scope FC always predicted for deontics
  - $\Rightarrow$ wide scope FC only if speaker knows what is permitted/obligatory
- Predictions confirmed by recent experiment (HLPC 2017): only in wide scope configurations FC dependent on speaker knowledge:

(22) We may either eat the cake or the ice-cream. [narrow, +fc]

(23) Either we may eat the cake or the ice-cream. [wide, +/–fc]

Position of *either* favors a narrow scope interpretation in (22), while it forces a wide scope interpretation in (23) (Larson 1985)

- Sluicing triggers wide scope configuration (Fusco 2015):

(24) You may either eat the cake or the ice-cream, I don't know which. [wide, –fc]

System B: some problems

Epistemic modals

- A (less worrying) version of Zimmermann's problem (Geurts 2005):

(25) $\Box a \vee_+ \Box b \models \Box a \wedge \Box b$ [if R is indisputable]

- Disjunctions of epistemic contradictions are not contradictory (Mandelkern's problem):

(26) $(a \wedge \Diamond\neg a) \vee (b \wedge \Diamond\neg b) \not\models \bot$ [even if R is state-based]

Exact vs inexact

- Although inexact, in system B: $a \not\equiv a \vee_+ (a \wedge b)$ (even though $a \equiv a \vee (a \wedge b)$);
- so Ciardelli & Aloni's strategy cannot apply.

Negation

- Behaviour under negation is postulated rather than predicted:
  - Allowing to pre-encode what should happen under negation, bilateral systems are more descriptive than explanatory (Ciardelli)

Troubles with negation: bilateral vs unilateral

- In bilateral systems behaviour under negation is postulated rather than predicted
- Alternatively we could adopt a unilateral system:
  - With *or* ambiguous between $\vee_+$ and $\vee$ plus a strongest meaning hypothesis (Aloni 07)
  - Where NE is ruled out from downward entailing contexts (NE as positive polarity item)
- In such a unilateral system, different results with different negations:
  - $s \models \neg_1 \phi$ iff $\forall t \subseteq s : t \models \phi \Rightarrow t = \emptyset$ [intuitionistic]
  - $s \models \neg_2 \phi$ iff $s \cap t = \emptyset$, for all $t : t \models \phi$ [incompatibility]

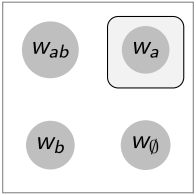


Figure: $\{w_a\} \models \neg_1(a \vee_+ b)$, but $\{w_a\} \not\models \neg_2(a \vee_+ b)$

A recent argument for a bilateral account

- Due to Romoli and Santorio (pc)
- Presupposition of second disjunct (Maria can go to study in Japan) does not project/filtered by negation of first disjunct in (27):

(27) a. Either Maria can't go study in Tokyo or Boston, or she is the first in our family who can go to study in Japan (and the second who can go to study in the States).

b. $\neg\Diamond(a \vee_{+} b) \vee \phi_{\Diamond a}$

- Assuming that a disjunction $\phi \vee \psi_P$ presupposes $\neg\phi \rightarrow P$, predicted presupposition for (27) is:

(28) $\neg\neg\Diamond(a \vee_{+} b) \rightarrow \Diamond a$

- In bilateral accounts of narrow scope FC (system B, Willer), (28) is a tautology (double negations cancel each other out and free choice inference is computed). Filtering is correctly predicted.

System B: some logical properties

- Double negation law:
  - $\phi \equiv \neg\neg\phi$
- De Morgan laws:
  - $\neg(\phi \vee \psi) \equiv \neg\phi \wedge \neg\psi$
  - $\neg(\phi \wedge \psi) \equiv \neg\phi \vee \neg\psi$
- But only a restricted version of addition:
  - $\phi \models \phi \vee \psi$ [if NE does not occur in ψ]

For comparison

- Hawke & Steinert-Threlkeld 2016:
  - $a \models_{HST} (a \vee b)$
  - $\Diamond a \not\models_{HST} \Diamond a \vee \Diamond b$
- Aloni 2007:
  - $\phi \models_A \phi \vee \psi$
  - $\Diamond a \not\models_A \Diamond(a \vee b)$

Summary

- Three notions of disjunction in state-based semantics:
  1. Possibility/dynamic semantics: $\vee_1$
  2. Team/assertability logic: $\vee_2$
  3. Inquisitive/truthmaker semantics: $\vee_3$
- System B: logical account of FC using an enriched version of $\vee_2$:
  - Narrow scope FC as entailments (well-behaving under negation)
  - Wide scope FC as entailments (dependent on accessibility relation)
  - FC effects also for plain disjunction and under $\Box$
- Other strategies lacked a ready account of wide scope FC

Future work

- Logical properties: implication and axiomatisation
- Dynamics
- Interaction deontics & epistemics
- Unilateral vs current bilateral version of the system
- Integration of state-based pragmatics (Aloni & Franke 2012)
- First order case
- ...

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