Information, issues, and live possibilities

Might in conflicts, free choice, and questions

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Two intriguing puzzles

Might in epistemic 'conflicts'

- Epistemic contradictions:

(1) #It might be raining but it isn't. $\Diamond p \wedge \neg p \equiv \bot$

- Epistemic disagreement:

(2) A: It might be raining. $\Diamond p$
B: No, it isn't. $\neg p$

- Epistemic incoherence:

(3) It isn't raining. [. . .] #It might be raining. $\neg p; \Diamond p$

Two intriguing puzzles

Puzzling because:

- *Might* is certainly not veridical

So we have $\Diamond p \not\models p$ but still $\Diamond p \wedge \neg p \equiv \bot$

- Incoherence effects disappear when order is reversed

(4) It might be raining. [. . .] It isn't raining. $\Diamond p; \neg p$

How to account for the asymmetry?
Impossible if update is intersective, and thus commutative.

Two intriguing puzzles

Free choice inferences

- Narrow scope disjunction:

(5) Sue might postpone or cancel. $\Diamond(p \vee q)$
$\rightsquigarrow$ she might postpone and she might cancel $\Diamond p \wedge \Diamond q$

- Wide scope disjunction:

(6) Sue might postpone or she might cancel. $\Diamond p \vee \Diamond q$
$\rightsquigarrow$ she might postpone and she might cancel $\Diamond p \wedge \Diamond q$

Two intriguing puzzles

Puzzling because:

Disjunction usually doesn't give rise to conjunctive inferences:

$$p \vee q \not\models p \wedge q$$

So why on earth would we have:

$$\Diamond p \vee \Diamond q \models \Diamond p \wedge \Diamond q$$

Prominent approach to epistemic conflicts

- Update semantics (Veltman 1996):
  - $s[p] = \{w \in s \mid w(p) = 1\}$
  - $s[\neg\varphi] = s \setminus s[\varphi]$
  - $s[\varphi \wedge \psi] = s[\varphi] \cap s[\psi]$
  - $s[\Diamond\varphi] = \begin{cases} s & \text{if } s[\varphi] \neq \emptyset \\ \emptyset & \text{otherwise} \end{cases}$
  - φ is accepted in s iff $s[\varphi] = s$
  - φ is unacceptable in s iff $s[\varphi] = \emptyset$
- Expressivist pragmatics (Yalcin 2007):
  - Assertion of φ is a proposal to make φ accepted in the CG.
  - Appropriate only if φ is already accepted in speaker's state.

Predictions

(7) #It might be raining but it isn't. $\Diamond p \wedge \neg p$

Feels contradictory because $\Diamond p \wedge \neg p$ is unacceptable in any state.

(8) A: It might be raining. $\Diamond p$
B: No, it isn't. $\neg p$

Perceived as disagreement because, if both assertions are appropriate, $\Diamond p$ is accepted in s_A but unacceptable in s_B.

(9) It isn't raining. [...] #It might be raining. $\neg p; \Diamond p$

Bad because $\Diamond p$ is always unacceptable in $s[\neg p]$.

(10) It might be raining. [...] It isn't raining. $\Diamond p; \neg p$

Ok, because $\neg p$ can be acceptable in $s[\Diamond p]$.

Possible approach to free choice inferences

- Attentional semantics (variant of Ciardelli et al 2009, Roelofsen 2013)

Informative content	Attentional content
$[p] = \{w \in s \mid w(p) = 1\}$	$[\![p]\!] = \{[p]\}$
$[\neg\varphi] = W \setminus [\varphi]$	$[\![\neg\varphi]\!] = \{[\neg\varphi]\}$
$[\varphi \wedge \psi] = s[\varphi] \cap s[\psi]$	$[\![\varphi \wedge \psi]\!] = [\![\varphi]\!] \cup [\![\psi]\!]$
$[\varphi \vee \psi] = s[\varphi] \cup s[\psi]$	$[\![\varphi \vee \psi]\!] = [\![\varphi]\!] \cup [\![\psi]\!]$
$[\Diamond\varphi] = W$	$[\![\Diamond\varphi]\!] = [\![\varphi]\!]$

- Attentional pragmatics (Ciardelli et al 2014, Westera 2017)
  - I-quality: speaker's epistemic state should support $[\varphi]$
  - A-quality: speaker's epistemic state should be compatible with all possibilities in $[\![\varphi]\!]$

Predictions

- Narrow and wide scope free choice are derived semantically:

$$\Diamond(p \vee q) \;\equiv\; \Diamond p \vee \Diamond q \;\equiv\; \Diamond p \wedge \Diamond q$$

- Speaker uncertainty is derived pragmatically: if Bill says $\Diamond p$, then by A-quality he must consider $[p]$ possible.

  Note: approaches that divide the labor between semantics and pragmatics in the opposite way fail to derive wide scope free choice.

- Interestingly, basic epistemic contradictions can also be explained pragmatically:
  - If Bill says $\Diamond p \wedge \neg p$, then:
  - By I-quality, s_B must be contained in $[\neg p]$
  - By A-quality, s_B must be compatible with $[p]$
  - These two things cannot be true at the same time.

Shortcomings of attentional semantics

- Yalcin (2007) argues that epistemic contradictions have to be accounted for semantically rather than pragmatically, because they occur embedded:

  (11) #If it might rain but it doesn't, Sue will leave.

- Unclear how attentional semantics could explain such cases.
- Also, no direct account of:
  - Epistemic disagreement
  - Incoherence effects.

Shortcomings of update semantics

- Doesn't account for free choice effects: $\Diamond(p \vee q) \not\equiv \Diamond p \wedge \Diamond q$
- Also fails to account for cases of epistemic conflict that involve free choice effects:

  (12) #Sue might postpone or cancel, but she won't cancel.
  $\Diamond(p \vee q) \wedge \neg q$

- At odds with the intuition that *might* assertions typically induce a non-trivial update (Willer 2013):

  (13) Mary: I can't find John. Do you know where he is?
  Alex: He might be at home.
  Mary: Oh, OK. I will call him and check.

Limitation of both approaches

- Both approaches focus on the use *might* in assertions.
- But *might* is also used in questions:

  (14) Might Peter be in Paris?

  (15) Where might Peter be?

- It is not evident how update semantics or attentional semantics could be extended to capture this use of *might*.

Summary

	conflicts	free choice	questions
Update semantics	+	–	–
Attentional semantics	–	+	–

Plan for today

Overcome the observed limitations by integrating two recently developed information-based semantic frameworks.

1. Update semantics with live possibilities (Willer 2013)

- Refinement of Veltman's update semantics.
- More fine-grained notion of information states, encoding:
  - The information available
  - The set of 'live possibilities'
- This allows Willer to capture the intuition that *might* assertions yield non-trivial updates: they introduce new live possibilities.
- Conceptually similar to attentional semantics, but does not directly account for free choice, nor for *might* in questions.

Plan for today

2. Inquisitive semantics (Ciardelli, Groenendijk, Roelofsen 2015)

- Developed to deal uniformly with statements and questions.
- Does not specify truth-conditions w.r.t. possible worlds, but rather support-conditions w.r.t. information states.
- $s \models \varphi$ just in case:
  - the information conveyed by φ is available in s and
  - the issue raised by φ is resolved in s
- For example:
  - $s \models p$ iff p is true in all $w \in s$
  - $s \models ?p$ iff p is true in all $w \in s$ or p is false in all $w \in s$
- Basic inquisitive framework does not deal with *might*.
- What should support-conditions for $?\Diamond p$ be? Certainly not:
  - $s \models ?\Diamond p$ iff p is true in some $w \in s$ or p is false in all $w \in s$

Plan for today

Concrete empirical aim

- Account for *might* in conflicts, free choice, and questions.

Broader theoretical aims

- Identify similarities and differences between inquisitive semantics and update semantics;
- Understand better which properties of update semantics are essential for dealing with *might*.

In particular, clarify/show that:

- The notion of support in inquisitive semantics and the notion of acceptance in update semantics (which is also often called support), are two different notions; they can and should be kept apart when combined in a single framework.
- *Might* can be dealt with in an eliminative framework, without giving up persistence of support (though acceptance will be non-persistent).
- In order to account for the asymmetric incoherence facts ($\Diamond p; \neg p$ versus $\neg p; \Diamond p$) a dynamic semantics is not really necessary. A static notion of semantic content suffices, in principle. Though updating cannot be purely intersective.

Note: Willer (2015, 2016) also combines live possibilities with inquisitive semantics to account for free choice effects, but his system is quite different from the one I will explore here. I will briefly return to this at the end.

Outline

Willer-style information states

- A Willer-style information state s is intended to capture:
  - The information available in s.
  - The set of live possibilities in s:

    Those possibilities of which it is established in s that they are to be taken seriously in inquiry.
- We will refer to Willer-style information states as attentional information states.

Willer-style information states

What does it mean to be taken seriously in inquiry?

Willer: “Consider an agent who sees an equid with black and white stripes and who wonders what kind of animal he or she sees. In most cases, the agent will ignore the possibility that the animal is a cleverly disguised mule and thus will see no reason not to accept the answer that the animal is a zebra on the basis of its outer appearance. But if the agent treats the possibility that the animal is a cleverly disguised mule as a relevant alternative, then the agent will not accept the answer that the animal is a zebra until he or she has eliminated the possibility that it is a cleverly disguised mule.”

Attentional information states, formally

- Let W be a set of possible worlds, our logical space.
- A possibility is a non-empty set of worlds $i \subseteq W$.
- An attentional information state s is a set of possibilities, determining:
  - $\text{info}(s) := \{w \mid w \text{ is contained in some } i \in s\} \quad = \cup s$
  - $\text{live}(s) := \{\, j \mid j \text{ is compatible with all } i \in s\}$
- This means that $\text{live}(s)$ is always closed under supersets.
- Intuitively, if i is to be taken seriously in inquiry, then any weaker possibility $j \supseteq i$ is to be taken seriously as well.

Attentional information states, formally

- We will often denote attentional info states as pairs:

$$\langle \text{info}(s), \text{live}(s) \rangle$$

  But for formal purposes it is sometimes convenient to switch to the set of possibilities s that determines this pair.
- To ensure that $\text{info}(s)$ and $\text{live}(s)$ uniquely determine s itself we assume that s always satisfies the following condition:
  - whenever $i \in s$ and $i \subseteq j \subseteq \cup s$ then also $j \in s$
- We also define:
  - $\text{rejected}(s) := \{\, i \mid i \cap \text{info}(s) = \emptyset\}$

Ordering attentional information states

Option A(ll)

- $s \leq_A t \quad \text{iff} \quad \text{info}(s) \subseteq \text{info}(t) \quad \text{and} \quad \text{live}(t) \subseteq \text{live}(s)$
- All information available in t is available in s as well.
- All possibilities live in t are live in s as well.
- Fact: $s \leq_A t \iff s \subseteq t$

Option C(ompatible)

- $s \leq_C t \;\text{ iff }\; \text{info}(s) \subseteq \text{info}(t) \;\text{ and }\; \text{live}(t) \subseteq \text{live}(s) \cup \text{rejected}(s)$
- All information available in t is available in s as well.
- All possibilities live in t are live in s as well, unless rejected.
- In other words: all possibilities live in t that are compatible with $\text{info}(s)$ are live in s as well.

Some examples

Let:

$$s_1 = \left\langle W, \{|p|\}^{\uparrow} \right\rangle \qquad s_2 = \left\langle W, \{|p|, |q|\}^{\uparrow} \right\rangle \qquad s_3 = \left\langle |\neg p|, \{|\neg p|\}^{\uparrow} \right\rangle$$

Then we have:

- $s_2 \leq_A s_1 \quad \text{but} \quad s_3 \not\leq_A s_1$
- $s_3 \leq_C s_1 \quad \text{but} \quad s_3 \not\leq_C s_2$

Issues

- As in Inq_B, issues are modeled as sets of information states: those in which the issue is settled.
- But now, instead of plain information states, we work with attentional information states.
- So, when determining whether a state s settles an issue $\mathcal{I}$, it may not just matter what the information available in s is, but also what the live possibilities in s are.
- Example: the issue expressed by *Might it rain tomorrow?* is settled in a state s just in case the possibility 'that it rains tomorrow' is live in s, or if it is rejected by s.

Two basic properties of issues

Just like in Inq_B:

- Issues are taken to be downward closed: we assume that if s settles an issue $\mathcal{I}$ then any A-extension $t \subseteq s$ settles $\mathcal{I}$ as well.
- Issues are assumed to be non-empty, because we take it that the absurd information state $\emptyset$ trivially settles any issue.

Alternatives

- Among the states that settle an issue, those that are minimal w.r.t. $\leq_A$ have a special status: they contain just enough information and live possibilities to settle the issue.
- As in Inq_B, we refer to these elements as alternatives.

$$\text{alt}(\mathcal{I}) := \{s \in \mathcal{I} \mid \text{there is no } t \in \mathcal{I} \text{ such that } s \leq_A t\}$$

- Unlike in Inq_B, however, one alternative may contain strictly more information than another alternative.
- Example: the issue expressed by $?\Diamond p$ will contain two alternatives in our system:

$$s_1 = \left\langle W, \{|p|\}^{\uparrow} \right\rangle \qquad s_2 = \left\langle |\neg p|, \{|\neg p|\}^{\uparrow} \right\rangle$$

s_2 contains strictly more information than s_1, but it does not have $|p|$ as a live possibility so $s_2 \not\leq_A s_1$.

Inquisitive states

- The inquisitive state of an agent is modeled as an issue.
- We assume that an agent's information state s and inquisitive state $\mathcal{I}$ are always related to each other in a particular way:
  1. $\text{info}(s) = \{w \mid w \in \text{info}(t) \text{ for some } t \in \mathcal{I}\}$
  2. $\text{live}(s) = \{i \mid i \in \text{live}(t) \text{ for all } t \in \mathcal{I}\}$
- The first requirement, inherited from Inq_B, ensures that $\mathcal{I}$ can be settled without discarding worlds that, for all is known in s, may well be the actual world.
- The second requirement says that i is a live possibility in s iff it is a live possibility in every information state that settles the issue that the agent entertains.

Inquisitive states

- It follows that the current attentional info state s of an agent can always be derived from her inquisitive state $\mathcal{I}$.
- After all, given $\mathcal{I}$, we know what info(s) and live(s) have to be, and these two objects in turn completely determine s itself.
- So we define:
  - info($\mathcal{I}$) $:= \{w \mid w \in$ info(t) for some $t \in \mathcal{I}\}$
  - live($\mathcal{I}$) $:= \{i \mid i \in$ live(t) for all $t \in \mathcal{I}\}$
  - att-info($\mathcal{I}$) $:= \{j \mid j \subseteq$ info($\mathcal{I}$) and compatible with all $i \in$ live($\mathcal{I}$)$\}$

Inquisitive states and conversational contexts

- So we have a single set-theoretic object (a non-empty, downward closed set of attentional information states) representing three aspects of an agent's state in one go:
  - the current information available to the agent,
  - the current live possibilities for the agent, and
  - the issue that the agent entertains,

    whose resolution may require establishing new information and/or establishing new live possibilities.
- Besides the state of an agent, the same kind of object can also be used to represent a conversational state/context.

Inquisitive propositions

- In inquisitive semantics the proposition $[\![\varphi]\!]$ expressed by a sentence φ is not a set of possible worlds, but an issue.
- This issue encodes the inquisitive content of φ.
- In uttering φ a speaker proposes to establish a CG in which the issue $[\![\varphi]\!]$ is settled.
- The informative and attentional content of φ can be derived from $[\![\varphi]\!]$:
  - info(φ) $:= \{w \mid w \in$ info(s) for some $s \in [\![\varphi]\!]\}$
  - live(φ) $:= \{i \mid i \in$ live(s) for all $s \in [\![\varphi]\!]\}$

Inquisitive propositions

- So again we have a single set-theoretic object representing three aspects of the meaning of a sentence in one go:
  - the issue it raises,
  - the information it conveys, and
  - the live possibilities it introduces.
- This formal object is the same type of object that is used to represent an agent's state andconversational contexts.
- One or more aspects of the meaning of φ may be trivial:
  - φ is non-informative iff info(φ) $= W$
  - φ is non-inquisitive iff $\langle$info(φ), live(φ)$\rangle \in [\![\varphi]\!]$
  - φ is non-attentive iff live(φ) $= \{$info(φ)$\}^{\uparrow}$

Logical language $\mathcal{L}_\diamond$

- Base language: standard first-order language $\mathcal{L}$.
- Additional operators:

$\diamond\varphi$	*might*
$!\varphi$	'declarative operator'
$?\varphi$	'question operator'

Translation examples

(16)	Sue might postpone or quit.	$!\diamond(p \vee q)$
(17)	Might Peter be in Paris?	$?\diamond p$
(18)	Where might Peter be?	$?\exists x.\diamond Px$

Semantics: preliminaries

- For any φ in the base language $\mathcal{L}$, we let $|\varphi|$ denote the set of worlds where φ is classically true.
- We recursively define a relation of support, $s \models \varphi$, between attentional info states and sentences.
- $[\![\varphi]\!]$ is the set of all attentional info states that support φ.
- We refer to the resulting system as Inq_{LP}, inquisitive semantics with live possibilities.

Semantics for base language: standard Inq_B

$s \models p$	iff	$\text{info}(s) \subseteq |p|$
$s \models \varphi \wedge \psi$	iff	$s \models \varphi$ and $s \models \psi$
$s \models \varphi \vee \psi$	iff	$s \models \varphi$ or $s \models \psi$
$s \models \varphi \rightarrow \psi$	iff	for all $t \leq_C s$: if $t \models \varphi$ then $t \models \psi$
$s \models \neg\varphi$	iff	for all $t \leq_C s$: if $t \models \varphi$ then $t = \emptyset$
$s \models \forall x.\varphi(x)$	iff	$s \models \varphi(d)$ for all $d \in D$
$s \models \exists x.\varphi(x)$	iff	$s \models \varphi(d)$ for some $d \in D$

- It is important that implication and negation quantify over all C-extensions of s, not just A-extensions.
- That is, we have to look at extensions where some of the live possibilities in s may be discarded.
- Otherwise we would get things like $\langle W, \{|\neg p|\}^{\uparrow}\rangle \models \neg p$.

Semantics for additional operators

- Might:

  $s \models \diamond\varphi$ iff $\text{live}(s) \supseteq \text{live}(t)$ for some $t \in \text{alt}(\varphi)$

- Declarative operator:

  $s \models !\varphi$ iff $\text{info}(s) \subseteq \text{info}(\varphi)$ and $\text{live}(s) \supseteq \bigcup\{\text{live}(t) \mid t \in \text{alt}(\varphi)\}$

- Question operator:

  $s \models ?\varphi$ iff $s \models \varphi \vee \neg\varphi$ (see appendix for generalization)

Two important properties

- Fact 1: The absurd state supports everything:

$$\text{For any } \varphi \in \mathcal{L}_\diamond : \quad \emptyset \models \varphi$$

- Fact 2: Support is persistent:

$$\text{If } s \models \varphi \text{ and } t \leq_A s \text{ then } t \models \varphi \text{ as well}$$

- So $[\![\varphi]\!]$ is always non-empty and downward closed, as desired.
- It may seem remarkable or even alarming that support is persistent in Inq_{LP} even though our language includes $\diamond$.
- But this is as it should be for the inquisitive notion of support.
- We will see that the dynamic notion of support/acceptance can be defined in our framework as well.
- This notion is indeed non-persistent due to the presence of $\diamond$.

Predictions: free choice

Conjunction over might

(19) John might speak English and he might speak French.

- Translation: $!(\diamond p \wedge \diamond q)$
- Simplified: $\diamond p \wedge \diamond q$
- $s \models \diamond p \wedge \diamond q$

  iff $s \models \diamond p$ and $s \models \diamond q$

  iff $\text{live}(s) \supseteq \{|p|, |q|\}^{\uparrow}$

Predictions: free choice

Disjunction under might

(20) John might speak English or French.

- Translation: $!\diamond(p \vee q)$ (cannot be simplified)
- $s \models \diamond(p \vee q)$

  iff $\text{live}(s) \supseteq \text{live}(t)$ for some $t \in \text{alt}(p \vee q)$

  iff $\text{live}(s) \supseteq \{|p|\}^{\uparrow}$ or $\text{live}(s) \supseteq \{|q|\}^{\uparrow}$
- So $\text{alt}(\diamond(p \vee q)) = \left\{ \begin{array}{c} \langle W, \{|p|\}^{\uparrow} \rangle \\ \langle W, \{|q|\}^{\uparrow} \rangle \end{array} \right\}$
- Thus: $s \models !(\diamond(p \vee q))$ iff $\text{live}(s) \supseteq \{|p|, |q|\}^{\uparrow}$
- So we account for narrow scope FC: $!\diamond(p \vee q) \equiv !(\diamond p \wedge \diamond q)$

Predictions: free choice

Disjunction over might

(21) John might speak English or he might speak French.

- Translation: $!(\diamond p \vee \diamond q)$ (cannot be simplified)
- $s \models \diamond p \vee \diamond q$

  iff $s \models \diamond p$ or $s \models \diamond q$

  iff $\text{live}(s) \supseteq \{|p|\}^{\uparrow}$ or $\text{live}(s) \supseteq \{|q|\}^{\uparrow}$
- So $\text{alt}(\diamond p \vee \diamond q) = \left\{ \begin{array}{c} \langle W, \{|p|\}^{\uparrow} \rangle \\ \langle W, \{|q|\}^{\uparrow} \rangle \end{array} \right\}$
- Thus: $s \models !(\diamond p \vee \diamond q)$ iff $\text{live}(s) \supseteq \{|p|, |q|\}^{\uparrow}$
- So we also predict wide scope FC: $!(\diamond p \vee \diamond q) \equiv !(\diamond p \wedge \diamond q)$

Predictions: negation over might

Basic case

(22) It is not the case that John might speak English.

- Simplified translation: $\neg\Diamond p$
- $s \models \neg\Diamond p$
  iff for all $t \leq_C s$: if $t \models \Diamond p$ then $t = \emptyset$
  iff $\text{info}(s) \cap |p| = \emptyset$
  iff $s \models \neg p$
- So, as desired: $\neg\Diamond p \equiv \neg p$

Predictions: negation over might

Disjunctive free choice cases

(23) It is not the case that John might speak English or French.

- Simplified translation: $\neg\Diamond(p \vee q)$
- $s \models \neg\Diamond(p \vee q)$
  iff for all $t \leq_C s$: if $t \models \Diamond(p \vee q)$ then $t = \emptyset$
  iff $\text{info}(s) \cap |p| = \emptyset$ and $\text{info}(s) \cap |q| = \emptyset$
  iff $s \models \neg p \wedge \neg q$
- So, as desired: $\neg\Diamond(p \vee q) \equiv \neg(p \vee q)$
- Same prediction for wide scope disjunction (shaky intuitions).

Predictions: negation over might

Conjunctive free choice case

(24) It is not the case that
John might speak English and he might speak French.

- Translation: $!\neg(\Diamond p \wedge \Diamond q)$ (cannot be simplified)
- $s \models \neg(\Diamond p \wedge \Diamond q)$ iff $s \models \neg p \vee \neg q$
- $s \models\, !\neg(\Diamond p \wedge \Diamond q)$ iff $\begin{cases} \text{info}(s) \subseteq |\neg(p \wedge q)| \text{ and} \\ \text{live}(s) \supseteq \{|\neg p|, |\neg q|\} \end{cases}$
- This seems ok, although intuitions about (24) are not clear.
- In any case, we predict that: $\neg(\Diamond p \wedge \Diamond q) \not\equiv \neg\Diamond(p \vee q)$
  which is generally considered a desirable result, and very difficult to get for semantic accounts of free choice.

Predictions: epistemic contradictions

Plain epistemic contradictions

(25) #It might be raining but it isn't.

- Translation: $!(\Diamond p \wedge \neg p)$
- Simplified: $\Diamond p \wedge \neg p$
- $s \models \Diamond p \wedge \neg p$
  iff $s \models \Diamond p$ and $s \models \neg p$
  iff $\text{live}(s) \supseteq \{|p|\}^{\uparrow}$ and $\text{info}(s) \subseteq |\neg p|$
  iff $s = \emptyset$
- So, as desired, $\Diamond p \wedge \neg p$ comes out as a contradiction.

Predictions: epistemic contradictions

Embedded epistemic contradictions

(26) #If it might be raining but it isn't, Sue will quit.

- Simplified translation: $(\Diamond p \wedge \neg p) \rightarrow q$
- Comes out as a tautology, just like $\bot \rightarrow \varphi$ for any φ.

Predictions: epistemic contradictions

Epistemic contradictions involving free choice

(27) #It might be raining or snowing, but it isn't snowing.

- Simplified translation: $\Diamond(p \vee q) \wedge \neg q$
- Comes out as a contradiction.
- Note: this case is not explained by previous accounts of epistemic contradictions (Veltman, Yalcin, Willer).
- Neither is it explained by pragmatic accounts of free choice (at least not straightforwardly), providing a new argument for a semantic approach.

Predictions: questions

Polar question with *might*

(28) Might Peter be in Paris?

- Translation: $?\Diamond p$
- $s \models ?\Diamond p$

  iff $s \models \Diamond p \vee \neg\Diamond p$

  iff $s \models \Diamond p \vee \neg p$
- Paraphrase: s resolves the issue expressed by $?\Diamond p$ iff
  - $|p|$ is a live possibility in s, or
  - $|p|$ is rejected in s.

Predictions: questions

Constituent question with *might*

(29) Where might Peter be hiding?

- Translation: $?\Diamond p$
- $s \models ?\exists x.\Diamond Px$

  iff $s \models \Diamond Pa \vee \Diamond Pb \vee \neg(Pa \vee Pb)$ assuming $D = \{a, b\}$
- Paraphrase: s resolves the issue expressed by $?\exists x.\Diamond Px$ iff
  - For some x, $|Px|$ is a live possibility in s, or
  - For all x, $|Px|$ is rejected in s.

Note: the framework needs to be extended to capture the presupposition of (29) that Peter is hiding somewhere.

Updating an inquisitive state

- To analyze epistemic disagreement and epistemic incoherence effects, we need a notion of update.
- Let $\mathcal{I}$ be an inquisitive state (conversational or of an agent).
- Let $\mathcal{I}[\varphi]$ denote the state resulting from an utterance of φ in $\mathcal{I}$.
- Recall that both $\mathcal{I}$ and $[\![\varphi]\!]$ are sets of information states.
- So, at first sight one may simply define: $\mathcal{I}[\varphi] := \mathcal{I} \cap [\![\varphi]\!]$
- Problem: does not allow us to discard live possibilities in $\mathcal{I}$.
- Solution:
  - First remove live possibilities in $\mathcal{I}$ that conflict with info(φ)
  - Then intersect with $[\![\varphi]\!]$

Updating an inquisitive state, formally

- Formally, we define:

$$\mathcal{I}[\varphi] = \mathcal{I} \upharpoonright \text{info}(\varphi) \cap [\![\varphi]\!]$$

  where:
  - $\mathcal{I} \upharpoonright \text{info}(\varphi) = \{s \upharpoonright \text{info}(\varphi) \mid s \in \mathcal{I}\}$
  - $s \upharpoonright \text{info}(\varphi) = \{i \cap \text{info}(\varphi) \mid i \in s\} \setminus \{\emptyset\}$
- $\mathcal{I}$ is first restricted to info(φ) and then intersected with $[\![\varphi]\!]$.
- Restriction operates in a pointwise way on each information state s in $\mathcal{I}$: it intersects every possibility $i \in s$ with info(φ).
- This ensures that the live possibilities in s that are incompatible with info(φ) are removed.
- As a consequence, they won't be live in $\mathcal{I} \upharpoonright \text{info}(\varphi)$ either.

Acceptance

- Following Veltman we say that φ is accepted in $\mathcal{I}$ iff $\mathcal{I}[\varphi] = \mathcal{I}$.
- This clearly differs from the inquisitive notion of support.
  1. Acceptance is a relation between sentences and contexts; Support is a relation between sentences and info states.

     Note: this difference does not arise if contexts are identified with info states, as is done in Veltman's update semantics, but here the two clearly come apart.
  2. Unlike support, acceptance is not persistent. For instance:
     - $\top[\Diamond p][\Diamond p] = \top[\Diamond p]$, so $\Diamond p$ is accepted in $\top[\Diamond p]$
     - $\top[\Diamond p][\neg p][\Diamond p] = \{\emptyset\}$, so $\Diamond p$ is not accepted in $\top[\Diamond p][\neg p]$

     So non-persistence, the hallmark of the notion of acceptance in standard update semantics, occurs in our system as well.

     Note: interestingly, acceptance *is* persistent in a restricted sense here: if φ is accepted in $\mathcal{I}$ then also in any $\mathcal{I}' \subseteq \mathcal{I}$.

Predictions: incoherence effects

- Recall:

(30)	It isn't raining. [. . .] #It might be raining.	$\neg p; \Diamond p$
(31)	It might be raining. [. . .] It isn't raining.	$\Diamond p; \neg p$

- This is predicted because:
  - $\top[\neg p][\Diamond p] = \bot$
  - $\top[\Diamond p][\neg p] = [\![\neg p]\!]$
- Unlike Veltman, Yalcin, and Willer, we also account for the free choice variant of the puzzle:
  - $\top[\neg p][\Diamond(p \vee q)] = \bot$
  - $\top[\Diamond(p \vee q)][\neg p] = [\![\neg p \wedge \Diamond q]\!]$

Predictions: epistemic disagreement

- Recall:

(32) A: It might be raining. $\Diamond p$
B: No, it isn't. $\neg p$

- Why is this perceived as a disagreement?
- Following Willer, we say that disagreement arises between two agents A and B w.r.t. a sentence φ whenever:
  - φ is accepted in A's state, i.e., $\mathcal{I}_A[\varphi] = \mathcal{I}_A$, and
  - φ is unacceptable in B's state, i.e., $\mathcal{I}_B[\varphi] = \bot$.
- Moreover, we assume that cooperativity requires that speakers only utter φ if φ is accepted in their own state.
- This allows us to derive that (32) amounts to a disagreement.
- Namely if both A and B are cooperative, it must be that $\Diamond p$ is accepted in A's state and unacceptable in B's state.

Conclusion

	conflicts	free choice	questions
Update semantics	+	–	–
Attentional semantics	–	+	–
Inq_{LP}	+	+	+

Other potential areas of application

- Modified numerals (Coppock and Brochhagen 2013)
- Conditionals, esp. Sobel sequences (Willer 2016)
- Resistance moves (Bledin and Rawlins 2016)
- Pragmatics (Westera 2017)

Disclaimer

- This is just a first sketch, many things remain to be explored.
- Willer (2015) also combines inqsem with live possibilities.
- His approach is different, in a way the reverse.
  - He takes issues as the basic structure, and builds a layer of attentional content on top.
  - Here, attentional information states are the basic objects and an inquisitive layer is built on top.
- I think this results in a setup where the main conceptual ideas from both traditions are most perspicuously preserved.
- Also, I think it allows more straightforwardly for a treatment of *might* in questions (not explicitly considered by Willer).
- But Willer's approach may have advantages, too.
The two need to be compared in more detail once the present approach is better worked out.

Thank you for your attention

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Appendix I: must

- One natural way to treat *must* in Inq_{LP} is as follows:

  $s \models \Box\varphi$ iff for every $t \leq_A s$ there is a $u \leq_A t$ such that $u \models \varphi$

- In words: $s \models \Box\varphi$ iff every way of extending s eventually leads to a state that supports φ.
- Inspired by data semantics (Veltman 1981).
- Note: we are only considering $\leq_A$-extensions of s, which means that the live possibilities in s must be preserved. So *must* is sensitive to live possibilities, just like *might*.
- This seems to make sense intuitively: $\Box\varphi$ is supported iff any way of extending our current information state which does not discard any of the possibilities that we are taking seriously in inquiry leads to a state that supports φ.
- It also guarantees that support remains persistent.

Appendix I: must

- Prediction: $\Box\varphi$ is strictly weaker than φ.
- Clearly, if $s \models \varphi$ then $s \models \Box\varphi$ (because support is persistent).
- To see that it is possible to support $\Box\varphi$ without supporting φ, consider the following example:
  - The possibility that Oswald killed Kennedy, $|p|$, is live in s.
  - The possibility that someone else killed Kennedy is not live, even though it is not completely ruled out by info(s).
  - Then: $s \models \Box Mo$ but $s \not\models Mo$.
- So, as in data semantics, we get an account of the intuition that $\Box\varphi$ is weaker than φ itself.
- Even though $\Box\varphi$ is weaker than φ, $\neg\varphi \wedge \Box\varphi$ and $\Box\varphi \wedge \neg\varphi$ are still predicted to be contradictions, as desired.
- Another prediction: $\Box\Diamond p$ and $\Diamond\Box p$ come out equivalent to $\Diamond p$. This seems right.

Appendix II: generalized question operator

- We took our logical language $\mathcal{L}_\Diamond$ to contain sentences of the form $?\varphi$ and defined:

  $s \models ?\varphi$ iff $s \models \varphi \vee \neg\varphi$

- This was a simplification.
- This is already clear from our translation of questions from English into $\mathcal{L}_\Diamond$, which does not only use ? but also $\exists$:

  (33) Where might Peter be? $?\exists x.\Diamond Px$

- To get such translations in a more principled way, we have to assume that $\mathcal{L}_\Diamond$ contains sentences of the form $?\vec{x}.\varphi$, where $\vec{x}$ is a sequence of variables (possibly empty), and that:

  $s \models ?\vec{x}.\varphi$ iff $s \models \exists\vec{x}.\varphi \vee \neg\exists\vec{x}.\varphi$

- If $\vec{x}$ is empty, we get the simplified clause.

Appendix III: disjunctive questions

Polar disjunctive questions without *might*

(34) Does Peter speak English-or-French$^{\uparrow}$?

- Translation: $?!(p \vee q)$

  where ! is contributed by intonation, roughly because the disjunction is pronounced as 'one block', see Roelofsen 2013 for details.

- Resolution requires establishing one of the following:
  - $!(p \vee q)$
  - $\neg p \wedge \neg q$

Appendix III: disjunctive questions

Polar disjunctive questions with *might*

(35) Might Peter speak English-or-French$^{\uparrow}$?

- Translation: $?!\Diamond(p \vee q)$ (! contributed by intonation)
- Resolution requires establishing one of the following:
  - $!\Diamond(p \vee q) \quad \equiv \Diamond p \wedge \Diamond q$
  - $\neg p$
  - $\neg q$

  Note: ‘negative’ resolution conditions are perhaps too strong.

Appendix III: disjunctive questions

Open disjunctive questions with *might*

(36) Might Peter speak English$^{\uparrow}$, or might he speak French$^{\uparrow}$?

- Translation: $?(\Diamond p \vee \Diamond q)$

  There is no ! here because the disjunction is not pronounced as ‘one block’, again see Roelofsen 2013 for details.
- Resolution requires establishing one of the following:
  - $\Diamond p$
  - $\Diamond q$
  - $\neg p \wedge \neg q$

Appendix III: disjunctive questions

Alternative questions with *might*

(37) Might Peter speak English$^{\uparrow}$, or might he speak French$^{\downarrow}$?

- Translation: $\Diamond p \vee \Diamond q$

  There is no ! here because the disjunction is not pronounced as ‘one block’; there is no ? either because of falling intonation; we are disregarding the presupposition that exactly one of the disjuncts holds, this could be added if we add presuppositions to the framework; see Roelofsen 2013, 2015.
- Resolution requires establishing one of the following:
  - $\Diamond p$
  - $\Diamond q$

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