

Notes on Epistemic Modals

Seth Yalcin, MIT

Amherst visit

10-12-06

Plan

1. **First Puzzle.** Describe some paradoxical effects that epistemic modals give rise to, and rule out some semantic theories that don't predict these effects. I will suggest that these effects undermine the view that epistemically modalized sentences have truth-conditions.
2. **Update semantics.** Sketch the dynamic semantics of Veltman [14] [15] and ask how well this theory accommodates the paradoxical effects, with special emphasis on the case of gradable epistemic modals.
3. **Second Puzzle.** Describe a second puzzle, this one raising a problem about how to characterize the gradable character of epistemic modals.
4. **Introducing probability measures.** Give an outline of a sketch of a proto-theory of epistemic modals which can handle both puzzles, building on ideas from Bayesian decision theory and from recent work on gradable adjectives.

Preliminary

- I will restrict attention mainly to the epistemic readings of
 - (a) the modal auxiliaries 'might' and 'must',
 - (b) the (sentential) adverbs 'possibly' and 'probably',
 - (c) the various sentential operators that can be constructed from the modal adjectives 'possible' and 'probable', such as 'it's (very) possible that', 'it's (very) probable that', 'there is a strong possibility that', 'is at least as probable as', 'is more probable than', etc., and
 - (d) those operators constructible from 'likely'.

and I assume as is standard that these all deserve broadly parallel semantic treatments, given the obvious inferential relations these operators bear to one another.

1 First puzzle: a paradox of epistemic modals

1.1 Moore's paradox

G.E. Moore long ago pointed out that sentences of the form $\lceil \phi$ and I don't know $\phi \rceil$, such as

- (1) It's raining and I don't know that it's raining.

are odd, contradictory-sounding, and generally unassertable at a context. This is taken to be *prima facie* puzzling, because these sentences are not, semantically, contradictions. They do not express necessarily false propositions.

How do we know they don't express necessarily false propositions?

- I. **Entertainability.** It's a totally trivial matter to entertain a possibility where, unbeknownst to you, it rains. This fact is reflected in the embedding behavior of Moore-paradoxical sentences. Sentences such as

- (2) Suppose that it's raining and you don't know that it's raining.

- (3) If it's raining and I don't know it, then I am not omniscient.

are perfectly interpretable. (Unlike contradictions in these environments.)

- II. **Entailment properties.** If (1) expresses a contradiction, it'd have to be because the propositions expressed by each conjunct are incompatible. That would mean that the proposition that it's raining entails the proposition that you know it's raining. But that's ridiculous.

So (1) is not a contradiction.

1.2 Epistemic modals and Moore's paradox

Now it has often been thought that, just like certain attitude verbs, epistemic modals can be used to generate Moore-paradoxical sentences (Hacking [5], Karttunen [7], Stalnaker [13], among others). For behold:

- (4) It isn't raining and it might be raining.

- (5) It isn't raining and it's probably raining.

Like MP-sentences, sentences with this structure— $\lceil \neg\phi$ and MIGHT $\phi \rceil$, or $\lceil \neg\phi$ and PROBABLY $\neg\phi \rceil$ —are odd, contradictory-sounding, and generally unassertable at a context, too.

Is this just Moore's paradox in a new guise? Before we make an official diagnosis, let us ask let us ask for reassurance that (4) and (5) really are not contradictory, as we did for (1); and let us use the same diagnostics we used for (1).

I. **Entertainability.** We noted that (1) was perfectly entertainable-as-true. Observe that this is not the case with (4).

- (1) It's raining and I don't know that it's raining.
- (4) It isn't raining and it might be raining.

This is a judgment we can support, not just by direct appeal to intuitions about the truth-conditions of (4), but also by consideration of the relevant embedding facts. Compare (2) and (7) to (6) and (8), respectively.

- (2) Suppose that it's raining and you don't know that it's raining.
- (6) # Suppose that it isn't raining and it might be raining.
- (7) If it's raining and I don't know it, then (still) it's raining.
- (8) # If it isn't raining and it might be raining, then (still) it isn't raining.

(6) and (8) are defective and not coherently interpretable.

Upshot: our first attempt at reassurance that (4) is a not contradiction fails: (4) is not entertainable as true in the way (1) is. In this respect, (4) is more like a straight contradiction.

Should we conclude, then, that (4) really is just contradictory? No; we should run the second “diagnostic” for contradictoriness we applied to Moore’s paradox.

II. **Entailment properties.** If (4) expresses a contradiction, it'd have to be because the propositions expressed by each conjunct are incompatible. That would mean that the proposition expressed by the second conjunct entails the negation of the first.

But that would mean that MIGHT ϕ entails ϕ .

Reductio. MIGHT is not a factive operator.

Upshot: The thesis that (4) is contradictory—that it expresses a necessarily false proposition—makes the *wrong predictions* about the entailment properties of the conjuncts.

1.3 A new paradox

- Dilemma: On the one hand, (4) is evidently not entertainable as true. On the other hand, reflection on the meanings of its individual conjuncts suggests that it should have non-empty truth-conditions.
- These two features do not play nice: assuming we do grasp the non-empty truth-conditions our sentence expresses (whatever these are), it seems there should be nothing at all preventing us from hypothetically entertaining the obtaining of these conditions. We ought to be able to do this simply as a matter of semantic competence.

That we cannot needs explanation.

- The trouble is that the truth-conditions of epistemically modalized sentences are subject to two conflicting demands. ‘MIGHT ϕ ’ must be such that, relative to a context:
 - a. The proposition expressed by ‘MIGHT ϕ ’ is truth-conditionally compatible with the proposition expressed by ‘ $\neg\phi$ ’.
 - b. The proposition expressed by ‘ $\neg\phi$ and MIGHT ϕ ’ is not entertainable as true.

Challenge for the defender of truth-conditional semantics: show how to meet these desiderata in a plausible way.

- The situation here is very unlike the case of Moore’s paradox. The challenge that Moore’s paradox presents is to explain the contradictory sound of a class of clearly non-contradictory sentences. This challenge can be met outside the compositional semantics and in the pragmatics—by appeal, for instance, to a norm of assertion.
- In contrast, the current problem—getting epistemic modals to have the two properties (a) and (b)—is clearly a semantic problem. It is a problem about finding the right truth-conditions for epistemic modal statements—truth-conditions that will satisfy apparently paradoxical demands.

1.4 Cleaning up

- Repeat all of the above for epistemic ‘(very) possibly’, ‘(very) likely’, ‘(very) probably’, ‘there is a (strong) possibility that’, etc.
- To generalize the embedding facts: Letting ‘ Δ ’ take as its substitution class epistemic modals,
 - # Suppose [$\neg\phi$ and $\Delta \phi$].
 - # Suppose [ϕ and $\Delta \neg\phi$].
 - # If [$\neg\phi$ and $\Delta \phi$], then ψ .
 - # If [ϕ and $\Delta \neg\phi$], then ψ .
- These generalizations also apply to epistemic ‘must’, the canonical dual of ‘might’. On the assumption that ‘must’ is factive, however, this is not really surprising.

1.5 Trouble for truth-conditional approaches

- According to standard approaches, epistemic modal statements have truth-conditions relative to a context and amount, basically, to descriptions of epistemic states: their truth values turn on whether some specified epistemic state(s) have some specified property.
- The simple problem: because these approaches all assign truth-conditions to ‘MIGHT ϕ ’ that are perfectly compatible with ‘ $\neg\phi$ ’, they make the incorrect prediction that what ‘ $\neg\phi$ and MIGHT ϕ ’-sentences say can be coherently entertained as true. Correlatively, these accounts end up with the wrong embedding predictions.

1.5.1 Epistemic modals as quantifiers over an indexically supplied domain

Basic structure:

$$\llbracket \text{MIGHT } \phi \rrbracket^c \text{ is true at } w \text{ iff } \exists w' \in R_c(w) : \llbracket \phi \rrbracket^c \text{ is true at } w'$$

We take R_c to be an indexically supplied function from worlds to sets of worlds (the modal base). (“Indexical” in the narrow sense of not being shiftable or bindable, like the English “I”.)

Various options for $R_c(w)$ have been proposed. The usual schema: $R_c(w)$ = the set of worlds compatible with what the agent(s) x F s, with authors differing on the selection of x and F . Examples: $R_c(w)$ = the set of worlds compatible with

- what the speaker of c knows at w (Moore [11])
- what the speaker of c can epistemically reach at w (Egan [2])
- what some salient agent in c knows at w
- what the “relevant community” at the c knows or could easily come to know at w (Hacking [5], DeRose [1])
- what the relevant community at c distributively knows at w (von Stechow and Giliès [3])

Etc.

Problem: No plausible combination x and F will generate the unpossibility we actually find in $\lceil \neg\phi \rceil$ and $\text{MIGHT } \phi \lceil$, and none will prevent the relevant embeddings.

Illustration: suppose

$$R_c(w) = \text{the set of worlds compatible with what the speaker at } c \text{ knows in } w$$

Then, relative to some fixed c , ‘it might be raining’ iff ‘I don’t know it isn’t raining’.
So these two have the same truth-conditions:

- (4) It isn’t raining and it might be raining.
- (9) It isn’t raining and I don’t know it isn’t raining.

But if these two sentences had the same truth-conditions, they’d be equally entertainable. They are not, as reflected in the embedding facts:

- (6) # Suppose it isn’t raining and it might be.
- (10) Suppose it isn’t raining and I don’t know it.
- (11) If it isn’t raining and I don’t know it, then there is a truth I don’t know.
- (12) # If it isn’t raining and it might be raining, then there is a truth I don’t know.

One can easily generate the same kind of minimal pairs with differing values for the relevant agent(s) x and the relevant evidential/epistemic relation F .

1.5.2 Epistemic modals as quantifiers over an indexically supplied, bindable domain

Speas’s examples. On the assumption that the epistemic modals invoke some kind of quantification over worlds, there is an even more straightforward problem with the idea of treating the (intension of) the restriction as a pure indexical, as illustrated by some examples due to Speas.

(13) [Every contestant]_{*i*} thinks they might_{*i*} be the winner.

Whether or not the quantifier binds the pronoun ‘they’, it appears that it needs to bind into the specification of the modal base. Else you’d end with a semantics that makes (13) equivalent to something like

(14) Every contestant thinks it is compatible with what I know that they are the winner.

(Or whatever, depending on the details of your indexical account.)

Fix. So, minimally, we need something more like

$$R_c(w) = \text{the set of worlds compatible with what } x \text{ knows in } w$$

where x —some sort of PRO—is (i) either left free and evaluated relative to a contextually supplied assignment function or (ii) is bound by a higher DP (referential or quantified) in the sentence, as above.

We can get a rough feel for the idea by using an “in view of” phrase (in the style of Kratzer) with an overt pronoun to articulate the modal base and cash out what “might_{*i*}” amounts to here.

(13) [Every contestant]_{*i*} thinks they_{*i*} might_{*i*} be the winner.

(15) [Every contestant]_{*i*} thinks that, in view of what they_{*i*} know, they_{*i*} might be the winner.

Paradox again. A fix like this is needed to handle Speas’s sentences. Does the one just sketched also capture the right predictions for our problematic sentences (6) and (8)?

(6) # Suppose that it isn’t raining and it might be raining.

(8) # If it isn’t raining and it might be raining, then (still) it isn’t raining.

No. Let the value of x be whatever you please...

(16) Suppose that it isn’t raining and it’s compatible with what x knows that it’s raining.

(17) If it isn’t raining and it’s compatible with what x knows that it’s raining, then (still) it isn’t raining.

...the result will be totally coherent, unlike (6) and (8).

2 Update semantics

2.1 The basic idea

- An obvious thought: considering yet again (6):

(6) # Suppose that it isn't raining and it might be raining.

If the modal here really does somehow express the compatibility of its prejacent with a body of information, evidently that body of information **includes the information carried by the other conjunct**. Maybe a semantics that makes *changing* or *updating* the informational context the central notion has the resources to capture this kind of context sensitivity.

- Enter the update semantics for ‘might’ of Veltman [14], [15]. The basic setup:
 - (I) Model a discourse context as body of information. (A set of worlds, the worlds compatible with what is presupposed.)
 - (II) Let the compositionally determined semantic value of a sentence in context be an operation on bodies of information—a function from (prior) contexts into (posterior) contexts.
- Declarative sentences will be usually be functions that take a context and map it into some subset of that context. (As in Stalnaker’s model of assertion.)
- ‘Might’ sentences will be different, however. The key effect of uttering MIGHT ϕ will *not* be to eliminate worlds from the context, but instead to perform a test—a test for the presence of ϕ -worlds.
- The idea (adjusting details) is that ‘might’ designates the function **might**, which behaves as follows:

$$\text{might}(p, c) = \begin{cases} c & \text{if } c \cap p \neq \emptyset; \\ \emptyset & \text{otherwise.} \end{cases}$$

Unembedded, MIGHT ϕ is “interpreted as making explicit that the negation of p is not presupposed in the context” (Stalnaker [12]).

2.2 Things to notice

- (i) The proposal abandons truth-conditions in a fundamental way.
- (ii) Much of the story about how MIGHT ϕ -sentences convey information is pragmatic.
- (iii) Insofar as the hearer learns something about the state of the world from the speaker’s utterance, the learning is indirect. It comes in when the hearer tries to work out *why* the speaker would bother to ensure that the negation of p is not presupposed in the context.

2.3 Paradox lost?

The proposal gives an account of what goes wrong with (4).

(4) It isn't raining and it might be raining.

- Say a sentence is **accepted** by a context just in case the update operation expressed by the sentence maps the context set to itself; and assume that a conjunct is accepted by a context if it is in the range of the update function expressed by each conjunct. Then the trouble with (4) is this: **no context simultaneously accepts the updates required by the two conjuncts.**
- The first conjunct is an assertion: its effect on the context set is to eliminate rain worlds. The effect of the second conjunct, by contrast, is to perform a test for the presence of rain worlds. The only context set in the range of both of these update functions is the empty set.
- On this account, our sentence sounds paradoxical because it is a destroyer of contexts. It is contradictory, not in a truth-conditional sense, but in a dynamic sense, in the sense of expressing an update function mapping every context to the empty set.

Nice features:

- **No weird entailment properties.** Although *MIGHT* ϕ and $\neg\phi$ are not dynamically compatible, it is not the case that *MIGHT* ϕ dynamically entails ϕ (a context can accept the update expressed by the former without accepting the update expressed by the latter). So we are not cornered into making 'might' factive.
- **Account of the problem with supposition.** The problem about supposing (4) is explained in structurally the same way as the case of assertion.

Assume that, according to the dynamic semanticist, to suppose what a sentence says is to entertain a body of information that is in the range of the update function expressed by the sentence (Heim [6]). Then (4) is exactly as supposable as the empty set of worlds—the desired result.

Upshot:

The embedding properties of $\lceil \neg\phi \text{ and } \text{MIGHT } \phi \rceil$ provide evidence in favor of the dynamic account of epistemic 'might'.

2.4 How to grade a test?

But what about the gradable case? Recall we have all the same problems with gradable epistemic modals, like 'probably'.

(5) It isn't raining and it's probably raining.

(18) # Suppose it isn't raining and it's probably raining.

(19) # If it isn't raining and it's probably raining, then...

What is the dynamic story about these modals supposed to be? Not clear; I am not familiar with any work here. Here's the best I can think of.

- Rewrite this:

$$\text{might}(p, c) = \begin{cases} c & \text{if } c \cap p \neq \emptyset; \\ \emptyset & \text{otherwise.} \end{cases}$$

as:

$$\text{might}(p, c) = \begin{cases} c & \text{if } \exists w \in c : p(w) = 1; \\ \emptyset & \text{otherwise.} \end{cases}$$

- Now, viewing c as the “modal base”, cut and paste Kratzer's ordering semantics to get test conditions for “probably”.

$$\text{probably}(p, c_{\leq}) = \begin{cases} c & \text{if } \forall w_1 \in c \cap \neg p : \exists w_2 \in c \cap p : w_2 \leq w_1 \\ & \text{and} \\ & \exists w_1 \in c \cap p : \forall w_2 \in c \cap \neg p : \neg(w_2 \leq w_1); \\ \emptyset & \text{otherwise.} \end{cases}$$

- The idea is that the gradability enters in at the level of test conditions: the “stronger” the modal intuitively is, the harder we make the test to pass.

Worries:

- i. **An informal worry.** the account is not incredibly intuitive. Unlike MIGHT ϕ , PROBABLY ϕ will almost never be already accepted in a given context. So it will almost end up having its “essential effect” on the context as the result of a repair strategy. (Possible fix: maybe what you want is the maximal subset of the context satisfying the test condition.)
- ii. **A formal worry.** There is a problem with the ordering semantics, independent of the attempted dynamic implementation. This brings us to the second puzzle.

3 Second puzzle: gradable epistemic modality

3.1 Review of ordering semantics

Recall how Kratzer's [9] semantics for 'probably' ("weak necessity") goes.

p is a **weak necessity** at w with respect to modal base f and ordering source g iff (restricting quantifiers to the modal base $f(w)$):

1. p is at least as good a possibility as $\neg p$.

$$\forall w_1 \in \neg p \exists w_2 \in p : w_2 \leq_{g(w)} w_1$$

2. $\neg p$ is not as good a possibility as p .

$$\exists w_1 \in p : \forall w_2 \in \neg p : \neg(w_2 \leq_{g(w)} w_1)$$

The intuitive picture: $f(w)$ determines a set of worlds, and $g(w)$ is used to partially order them. We do not assume that there are minimal elements; for now I restrict myself to the case where the limit assumption fails. Think of the partial order as determining a bunch of infinitely descending chains (total orders). For each proposition p , these chains come in three varieties: they either

- i. descend infinitely into p ,
- ii. descend infinitely into $\neg p$,
- iii. alternate infinitely between p and $\neg p$ as you descend.

A proposition p will then be a weak necessity/probable just in case no chains descend infinitely into $\neg p$, and at least one chain descends into p .

A very nice feature of this semantics: according to it, this inference pattern is correctly predicted not valid:

probably p

probably q

\therefore probably $(p \wedge q)$

The trouble with this inference pattern can be seen in simple lottery cases.

Three people, A, B, and C, play a lottery. There will be one winner, randomly chosen. Given these odds, it's more likely that A will lose rather than win. That is, A will probably lose. Likewise, B will probably lose. It is not probable, however, that A and B will (both) lose. (In fact it is more likely than not that one of A or B will win.)

(Related worries about the inference pattern can be found in Kyburg [10])

Hard to see how to get this nice feature without denying the limit assumption. (The limit-assumption-based semantics tentatively proposed in the lecture notes of von Stechow and Heim [4], which involve only universal quantification over a fixed set of worlds, appears to license this problematic inference.)

3.2 Trouble

It seems there are some problems, however.

3.2.1 Upward probability transfer

Consider the following inference pattern, which I will call *upward probability transfer*.

Upward Probability Transfer

It is probable that p .
 q is as at least as probable as p .
 \therefore It is probable that q .

Claim: this is a valid inference pattern.

Example. That Sally is in her office is at least as probable (or ‘as likely’, or ‘as good a possibility as’) as Steve’s being in his office. In fact, Steve is probably in his office. So, Sally is probably in her office.

Claim: the semantics for probability operators of Kratzer [9] does not validate this inference pattern.

Counterexample. Consider a set of worlds (determined by a modal base evaluated at w) totally ordered by \leq (determined by an ordering source evaluated at the same w). Let this chain

1. descend into p and
2. alternate infinitely between q and $\neg q$ as you descend.

Then relative to this set of worlds and order, p is probable (in fact, necessary), and q is at least as likely as p (because for every p -world there is a better q world); but q is not probable, because we have no chain descending into q .

So the semantics is not correct.

3.2.2 Downward probability transfer

There is a “dual” inference pattern that generates exactly the same problem:

Downward Probability Transfer

It is not probable that p .
 p is as at least as probable as q .
 \therefore It is not probable that q .

Claim: the semantics for probability operators of Kratzer [9] does not validate this inference pattern, either.

Counterexample. Same structure as above, just switching p and q .

3.3 Some thoughts that may look reasonable at this point

An internal dialogue you might have at this stage:

“In math, probability is treated as a measure-theoretic notion. Maybe English treats it this way too. That is, maybe the semantics for English probability operators requires explicit reference to probabilities and (therefore) to probably measures. Why think this? First, we’ve just seen that there are difficulties trying to cash ordinary language probabilistic notions out with just a partial order over accessible worlds. It looks like we need more structure. Second, probability talk uses all the usual degree morphology that comes with gradable adjectives—comparative morphemes (more, less), intensifiers (very, quite, rather), sufficiency morphemes (too, enough, so), etc.—and it is widely thought that gradable adjectives are best analyzed via explicit reference to a domain d of degrees. Maybe probability operators are just like ordinary gradable adjectives, making references to degrees (and specifically, probabilities).

“So perhaps the thing to do is look at what is available in the literature on gradable adjectives and see what we can build on.”

What follows is some speculation on a direction to take, inspired by Kennedy [8].

4 Closing remarks: first steps into probability

The idea is to see if we can find a formal analogy between gradable adjectives and epistemic modals. I am only interested in the big picture at this point.

4.1 Comparatives

Start simple, by giving the semantics for ‘is more probable than’ on the model of (e.g.) ‘is larger than’. Suppose the semantics for comparative constructions is roughly of this form (Kennedy [8]):

$$\llbracket \text{is larger than} \rrbracket = \lambda y \lambda x. \mathbf{large}(x) > \mathbf{large}(y)$$

where **large** is a **measure function** mapping objects to their sizes. Then let epistemic modal comparatives be functions on propositions, and let the relevant measure functions be probability measures.

$$\llbracket \text{is more probable than} \rrbracket = \lambda q \lambda p. Pr(p) > Pr(q)$$

4.2 Positive forms

Suppose the semantics for the “positive form” a gradable adjective (‘large’, ‘expensive’) looks roughly like this (Kennedy, forthcoming):

$$\llbracket \text{large} \rrbracket = \lambda x. \text{large}(x) > \mathbf{d}$$

where \mathbf{d} is the contextually appropriate standard of evaluation, whatever that is.¹ Then let ‘probably’ mimic this:

$$\llbracket \text{probably} \rrbracket = \lambda p. Pr(p) > \mathbf{d}$$

Usually \mathbf{d} will be understood to be $Pr(\neg p)$, and is therefore interpreted as 0.5. (But this is in fact not always the case.)

4.3 Absolutes

Kennedy [8] argues that some adjectives are **absolute**, serving to characterize the degree to which an object has a property by reference to the upper and lower bounds of the relevant scale.

Two varieties:

- **Minimum Standard:** adjectives which compare the degree of x to the lower bound of the scale.
 - The door is open.
 - The rod is bent.

Only non-zero door aperture/degree of bend required for truth.

$$\llbracket \text{bent} \rrbracket = \lambda x. \text{bend}(x) > \min(\mathbf{bend})$$

- **Maximum Standard:** adjectives which compare the degree of x to the upper bound of the scale.
 - The door is closed.
 - The rod is straight.

Requires completely closed door/completely straight rod.

$$\llbracket \text{straight} \rrbracket = \lambda x. \text{straight}(x) = \max(\mathbf{straight})$$

One might suspect that a parallel treatment could apply to the ‘core’ epistemic modals:

$$\begin{aligned} \llbracket \text{possibly} \rrbracket &= \lambda p. Pr(p) > \min(Pr) \\ \llbracket \text{must} \rrbracket &= \lambda p. Pr(p) = \max(Pr) \end{aligned}$$

¹There are totally nontrivial issues about how exactly to fix \mathbf{d} ; I am setting these complications aside for now.

4.4 The new cast

One-place epistemic modal operators:

- $\llbracket \text{possibly} \rrbracket = \lambda p. Pr(p) > 0$
- $\llbracket \text{probably} \rrbracket = \lambda p. Pr(p) > 0.5$ (usually)
- $\llbracket \text{must} \rrbracket = \lambda p. Pr(p) = 1$

Two-place epistemic modal operators:

- $\llbracket \text{is more probable than} \rrbracket = \lambda q \lambda p. Pr(p) > Pr(q)$
- $\llbracket \text{is at least as likely as} \rrbracket = \lambda q \lambda p. Pr(p) \geq Pr(q)$

These operators inherit various nice properties of probability measures. As a consequence, they have probability transfer covered.

Positive Probability Transfer

It is probable that p .	$Pr(p) > 0.5/d$
q is as at least as probable as p .	$Pr(q) \geq Pr(p)$
\therefore It is probable that q .	$\therefore Pr(q) > 0.5/d \quad \checkmark$

Negative Probability Transfer

It is not probable that p .	$Pr(p) < 0.5/d$
p is as at least as probable as q .	$Pr(p) \geq Pr(q)$
\therefore It is not probable that q .	$\therefore Pr(q) < 0.5/d \quad \checkmark$

4.5 Back to the original paradox

It still remains to say what, exactly, these probability measures are supposed to represent in context. I think that if this question is answered in the right way, a natural explanation for what is going on with sentences like

- (4) It isn't raining and it might be raining.
- (5) It isn't raining and it's probably raining.

becomes available. The key thing *not* to do is to treat these probability measures as descriptions of epistemic states or of bodies of information in worlds, deriving truth-conditions accordingly.

The rough idea, proposed in Yalcin [16], is tht epistemic modal statements serve, in the first instance, to distinguish the probabilities or likelihoods of possibilities, and not merely to distinguish between possibilities, as advocates of standard truth-conditional approaches maintain.

We use these claims to express our partial beliefs. My suspicion is that, in order to model the content effects of these statements—the changes they make to communicative contexts—we need an additional layer of information in our representation of the context, one playing something like the role that credence functions play for the Bayesians. We need to use, not just a set of worlds, but a set of probability measures to represent the discourse context. This will let us use sets of probability measures as the semantic content of epistemic modal claims. If we have this, we can think of epistemic modal claims—and ordinary claims generally—as eliminating probability measures from the context.

To cover the puzzling conjunctions, assume that ordinary assertions will rule out all those measures that map the propositions being asserted to a value less than 1.

References

- [1] K. DeRose. Epistemic possibilities. *Philosophical Review*, 100(4):581–605, 1991.
- [2] A. Egan. Epistemic modals, relativism, and assertion. In J. Gajewski, V. Hacquard, B. Nickel, and S. Yalcin, editors, *New Work on Modality*, pages 35–63. MIT Working Papers in Linguistics, 2005.
- [3] K. von Fintel and A. Gillies. “Might” made right. Unpublished handout, 2004.
- [4] K. von Fintel and I. Heim. Intensional semantics lecture notes. Unpublished, 2005.
- [5] I. Hacking. Possibility. *Philosophical Review*, 76(2):143–68, 1967.
- [6] I. Heim. Presupposition projection and the semantics of attitude verbs. *Journal of Semantics*, 9:183–221, 1992.
- [7] L. Karttunen. Possible and must. In J. Kimball, editor, *Syntax and Semantics 1*. Academic Press, 1972.
- [8] C. Kennedy. Vagueness and grammar: The semantics of relative and absolute gradable adjectives. forthcoming in *Linguistics and Philosophy*, 2006.
- [9] A. Kratzer. Modality. In A. von Stechow and D. Wunderlich, editors, *Semantics: An International Handbook of Contemporary Research*, pages 639–50. de Gruyter, 1991.
- [10] H. Kyburg. Conjunctivitis. In M. Swain, editor, *Induction, Acceptance, and Rational Belief*. Reidel, Dordrecht, 1970.
- [11] G. E. Moore. *Commonplace Book 1919-1953*. George, Allen, and Unwin, London, 1962.
- [12] R. Stalnaker. Pragmatics. *Synthese*, 22:272–89, 1970.
- [13] R. Stalnaker. A defense of conditional excluded middle. In W. Harper, R. Stalnaker, and G. Pearce, editors, *Ifs*, pages 87–104. Reidel, Dordrecht, 1981.
- [14] F. Veltman. Data semantics and the pragmatics of indicative conditionals. In E. Traugott, A. ter Meulen, J. Reilly, and C. Ferguson, editors, *On Conditionals*, pages 147–68. Cambridge University Press, 1986.

- [15] F. Veltman. Defaults in update semantics. *Journal of Philosophical Logic*, 25(3):221–61, 1996.
- [16] S. Yalcin. Epistemic modals. In J. Gajewski, V. Hacquard, B. Nickel, and S. Yalcin, editors, *New Work on Modality*, pages 179–207. MIT Working Papers in Linguistics, 2005.