

Lecture 13. Intensionality, Referential Opacity, Modality, Possible Worlds

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Suggested Readings:

- (i) Zimmermann, Ede. 1993. On the proper treatment of opacity in certain verbs. *Natural Language Semantics* 1:149-179. (Zimmermann 1993)
- (ii) Kratzer, Angelika. 1981. The notional category of modality. In *Words, Worlds, and Contexts. New Approaches to Word Semantics*, eds. H.-J. Eikmeyer and H. Rieser, 38-74. Berlin: de Gruyter. Reprinted in Portner and Partee, eds., 2002, 289-323. * (Kratzer 1981) (on CD)
- (iii) Portner, Paul. 1997. The Semantics of Mood, Complementation, and Conversational Force. *Natural Language Semantics* 5:167-212. (Portner 1997)
<http://people.umass.edu/partee/docs/portnerNLS1997.pdf>
- (iv) Partee, Barbara H. (in press) Weak noun phrases: semantics and syntax. To appear in the proceedings of Dialog 2005, Moscow. (Partee in press)
http://people.umass.edu/partee/docs/Partee_Dialog2005.pdf

Additional Recommended Readings

- Maribel Romero, course handout April 5, 2005: "Intensionality":
<http://babel.ling.upenn.edu/courses/ling255/Intensionality.pdf>
- (Kiparsky and Kiparsky 1970)
- (Partee 1974) * (available on CD)
- (von Fintel 2001) (preprint available at <http://mit.edu/fintel/www/conditional.pdf>)
- von Fintel, Kai and Irene Heim (in progress). Draft chapters of a new textbook on Intensionality. Chapters 1-3.* (on CD)
- (Lewis 1978) Translated into Russian by A.D. Šmelev.* (on CD)
- (Dayal 2004) * (on CD)
- (Larson 2002) <http://semanticsarchive.net/Archive/WVhMGRhN/larson.intens.pdf>

1. Intensionality

Montague's Intensional Logic (IL) was presented in Lecture 2, but we have not made any use of its intensional aspects; we have been working with extensional parts of it. Today we very quickly introduce the big topic of intensionality, and after a brief general introduction, we

* The items marked with a * are available on a CD "semantics readings 2005" that the MGU students made and shared; I will bring a copy to RGGU, to the 'reading room collection', so you can borrow it to make copies for yourselves if you wish.

will concentrate on the question of whether "non-referential" NPs should sometimes be given "property-type" interpretations.

Intensions and extensions. This distinction goes back to Frege (Frege 1892), who distinguished *Sinn* and *Bedeutung*: variously translated as "sense and reference", "sense and denotation", "meaning and denotation". Carnap (Carnap 1956) formalized Frege's distinction and introduced the terminology "intension and extension", which has become standard in logic and formal semantics.

The need for distinguishing intensions and extensions. The principle of compositionality requires that the meaning of an expression is a function of the meanings of its parts and of the way they are syntactically combined. This requirement gives rise to *substitutivity tests*.

Example 1: non-intersective adjective + common noun phrase

What is the semantic type of the meaning of *violinist*? We have analyzed it as a common noun, type $\langle e, t \rangle$, which means that it denotes a set of individuals: the set of violinists. Similarly for *surgeon*. But when we discussed the meaning of non-intersective adjectives like *skillful*, we showed, in effect, that substitution of one noun for another noun picking out the same set does NOT always preserve truth-value:

- (1) a. John is a skillful surgeon.
- b. John is a skillful violinist.

In a possible state of affairs in which the set of surgeons is identical to the set of violinists, it is possible for (1a) to be true and (1b) false, and vice versa.

Frege's solution, in the version in which it was adapted by Carnap and then Montague, is to say that a noun like *surgeon* has both an *intension* and, in each possible state of affairs, an *extension*. The *intension* is closer to what we intuitively think of as the meaning of the expression: Montague formalized it as a function which applies to possible worlds, or possible states of affairs, and picks out in each possible state of affairs the set of surgeons in that state of affairs.

And in the expression *skillful surgeon*, Montague (following Kamp, Parsons, and Clark) argued that the adjective denotes a function that applies to the *intension* of the common noun phrase. And since the intensions of *violinist* and *surgeon* are clearly different, it is not surprising that (1a) and (1b) can have different truth values even in a situation in which the *extensions* of *violinist* and *surgeon* are the same.

In the case of expressions of type $\langle e, t \rangle$, the extension at each possible world is a set of individuals; the intension is a *property* of individuals, formalized (in Montague's IL) as a function from possible worlds to sets of individuals.

Example 2: Definite NPs with predicates of 'change'.

- (2) The U.S. President is gaining power.

The predicate "is gaining power" can apparently be applied to either the intension or the extension of the subject term; similar effects are found with verb phrases like *is changing*, *is becoming less popular in many parts of the world*. These examples illustrate a 'temporal' dimension; Montague treated possible worlds and times in a parallel way. On one interpretation, those predicates apply to George W. Bush; on the other interpretation, (2) applies to the "president-function", asserting that each president has more power than the previous one.

For expressions of type *e*, the extension is an entity; the intension is an *individual concept*, formalized in IL as a function from possible worlds to individuals.

Example 3: ‘Intensional transitive verbs’ with NP objects

- (3) John is looking for the owner of the Mercedes
The owner of the Mercedes is the president of the bank

Therefore ? John is looking for the president of the bank

The *failure of substitutivity* of coreferential terms in the context *John is looking for _____* is the principal diagnostic for calling that context *non-extensional*. [Also called *referentially opaque* (Quine).] It contrasts with an *extensional context* such as *John is standing next to _____*. [also called *referentially transparent* (Quine).]

The idea for a compositional semantics for constructions involving opaque or non-extensional contexts traces back to Frege and was further developed by Carnap, Kripke, Montague. It involves Frege’s distinction between *Sinn* and *Bedeutung*, developed by Carnap as *intension* vs. *extension*.

We typically refer to verbs like *seek*, *look for*, *want* as “intensional verbs”, but really we mean verbs whose object must be interpreted intensionally: to account for the failure of substitutivity, we argue that the verb combines semantically not with the extension of its direct object, but with its intension. If the type of the object is taken to be type *e*, then this is another case of an *individual concept*; if it is taken to be a generalized quantifier, then the intension has no special name, it is just “the intension of a generalized quantifier”, i.e. a function from possible worlds to generalized quantifier denotations (sets of sets of individuals).

Example 4: Propositional attitude verbs and embedded clauses.

- (4) a. John believes that March 15, 2005, was a Wednesday.
b. John believes that January 25, 2005, was a Wednesday.

Suppose that (4a) is true. Now, in fact, both of those days were Tuesdays, so both embedded clauses are false. And suppose we say that the extension of a sentence is its truth value. Well, obviously we don’t want to use the extension of the embedded sentence in computing the truth-conditions of the whole sentence – otherwise we would be predicting that if John believes one false sentence, he believes “the false”, i.e. he believes any false sentence. We would predict that if (4a) is true, (4b) must be true, too. Instead, we want (at least) the *intension* of the embedded sentence to contribute to the extension of the whole sentence. This helps account for two facts: first, that substituting a sentence with the same truth value does not always preserve the truth of the whole sentence, and second, that in fact the truth value of the embedded sentence may be quite irrelevant to the truth value of the whole sentence.

For expressions of type *t*, the extension is a truth value, and the intension is a *proposition*, formalized in IL as a function from possible worlds to truth values, or equivalently, as a set of possible worlds. If you know the intension of a sentence, then in principle, you know how to divide the set of possible worlds into the ones where the sentence is true and the ones where it’s false. (“In principle”, because it requires being “given” the possible worlds as arguments, which is hard to do in any direct way, and may sometimes be hard to do at all. But sometimes it’s clear enough.)

Possible worlds. There is lots of philosophical discussion of possible worlds; and if we want to enrich them with various aspects of contexts like time and place and point of view, it may be better to work with “parts” of possible worlds, what Kratzer takes as *possible situations* (Kratzer 1989). (This is different from the situation theory of Barwise and Perry (Barwise and Perry 1983), which is not intensional, and therefore many of us consider it inadequate.) While there may be very real philosophical debates about the ontological status of alternative possible worlds or alternative possible situations, there can hardly be any doubt that they are cognitively fundamental. I would argue that even dogs and prelinguistic infants have conceptions of alternative possible states of affairs, and that any indication of “surprise” is good evidence of this: surprise is a reaction to a mismatch between an *expected* state of affairs and a *perceived* state of affairs, and without the possibility of conceiving of things as being different from how they actually are, we couldn’t be surprised. (Remind me to tell my anecdote about Robin Cooper’s dog and how I came to realize that dogs conceptualize alternative states of affairs and can be surprised.)

Modal logic.

For this, I refer you to Maribel Romero’s class handout from April 5, 2005: <http://babel.ling.upenn.edu/courses/ling255/Intensionality.pdf> . (Thank you, Maribel!) I will return below to some examples involving different senses of modal verbs like *must*, *can*, *may* and different kinds of ‘accessibility relations’ between possible worlds that help explain their different but related senses – from the classic work of Kratzer (1977).

Intensional type theory.

Maribel introduced the fundamentals of intensionality without involving the full type theory; her intensional operators were all operators that apply to a sentence, and make use of the distinction between *truth value* and *proposition*. Some philosophers and some linguists (see Larson 2002) believe that all intensional contexts in natural language are proposition-embedding contexts. That is a very interesting debate, and some of the arguments pro and con are discussed in Larson (2002); his conclusion is ‘pro’; I would continue to argue ‘con’. Before Montague introduced his higher-order typed intensional logic, it was difficult to see how to avoid decomposing all intensionality into proposition-embedding constructions, often at considerable violence to the syntax. But Montague designed his type theory so that for *every* extensional type there is a corresponding intensional type. Recall his type theory from Lecture 2:

The types of Montague’s IL are as follows:

Basic types: *e* (entities), *t* (truth values)

Functional types: If *a, b* are types, then $\langle a, b \rangle$ is a type (the type of functions from *a*-type things to *b*-type things.)

Intensional types: If *a* is a type, then $\langle s, a \rangle$ is a type (the type of functions from possible worlds to things (extensions) of type *a*.)

Montague’s IL also includes two rules specifically relating to intensions and extensions.

Syntactic Rule 4: (“up”-operator.) If $\alpha \in ME_a$, then $[\wedge \alpha] \in ME_{\langle s, a \rangle}$.

Semantic Rule 4: $\| [\wedge \alpha] \|^{M, w, g}$ is that function *h* of type $\langle s, a \rangle$ such that for any *w’* in *W*,
 $h(w') = \| \alpha \|^{M, w', g}$.

Syntactic Rule 5: (“down”-operator.) If $\alpha \in \text{ME}_{\langle s, a \rangle}$, then $[\forall \alpha]_0 \text{ME}_a$.

Semantic Rule 5: $\| [\forall \alpha] \|^{M, w, g}$ is $\| \alpha \|^{M, w, g(w)}$

And there is also the necessity operator of modal logic, and a “PAST” operator:

Semantic Rule 2:

(a) $\neg \phi, \phi \& \psi, \phi \vee \psi, \phi \rightarrow \psi, \phi \leftrightarrow \psi, \exists u \phi, \forall u \phi$ as in predicate logic.

(b) $\| \Box \phi \|^{M, w, g} = 1$ iff $\| \phi \|^{M, w', g} = 1$ for all w' in W .

(c) $\| \text{PAST } \phi \|^{M, w, g} = 1$ iff $\| \phi \|^{M, w', g} = 1$ for some $w' \leq w$. (This is a simplification; here we are treating each w as a combined “world/time index”, possibly a situation index; $w' \leq w$ if w' is a temporally earlier slice of the same world as w .)

Examples of expressions of IL and their types:

Type e: $\lambda x(\text{president}(x))$ (“the president” in type e: review Lecture 2)

Type $\langle s, e \rangle$: $\lambda x(\text{president}(x))$

Type $\langle e, t \rangle$: surgeon ; violinist ; $\lambda x[\text{love}(x)(\text{Mary})]$; $\lambda x \text{surgeon}$

Type $\langle s, \langle e, t \rangle \rangle$: $\lambda x \text{surgeon}$; $\lambda x[\text{love}(x)(\text{Mary})]$

Type t: $\text{love}(\text{John})(\text{Mary})$ ‘Mary loves John’

Type $\langle s, t \rangle$: $\lambda x \text{love}(\text{John})(\text{Mary})$ ‘that Mary loves John’

Generalized quantifiers, type $\langle \langle e, t \rangle, t \rangle$: $\lambda P \exists x[\text{unicorn}(x) \& P(x)]$ ‘a unicorn’

Intension of gen. quantifier, type¹ $\langle s, \langle \langle e, t \rangle, t \rangle \rangle$: $\lambda P \exists x[\text{unicorn}(x) \& P(x)]$

Montague’s type for *seek*: a function from intensions of generalized quantifiers, i.e.

$\langle s, \langle \langle e, t \rangle, t \rangle \rangle$, to VP-type, i.e. $\langle e, t \rangle$. Altogether: $\langle \langle s, \langle \langle e, t \rangle, t \rangle \rangle, \langle e, t \rangle \rangle$.

2. Linguistic mood and intensionality

One good example of a place where there is linguistic marking of an extensional/intensional distinction is in the indicative/subjunctive alternation in some constructions in Spanish and other Romance languages. (Not only those, but those are the ones I know best.)

Caveat: not all instances of indicative/subjunctive choice in Romance languages are direct reflections of a semantic distinction: in some cases one choice or the other is obligatory, and appears to have become “syntacticized” or otherwise “frozen”. Compare obligatory Genitive of Negation in certain fixed expressions in Czech, where Genitive of negation has disappeared as a productive process. And in Russian, genitive is still used in some fixed expressions where the productive rules would predict accusative – remnants of an earlier period when genitive was the norm for all negated objects, as it is now in Polish.

But there are clearly some cases where indicative/subjunctive in Spanish marks a semantic distinction.

¹ Actually, since Montague built intensionality into his types more systematically, the type for a plain generalized quantifier would be a set of properties rather than a set of sets, so $\langle \langle s, \langle e, t \rangle, t \rangle \rangle$, and then the intension of a generalized quantifier would be $\langle s, \langle \langle s, \langle e, t \rangle, t \rangle \rangle \rangle$. (Even here I have simplified, following arguments presented by Michael Bennett (Bennett 1976, Bennett 1974), in keeping the type of extensions of common nouns as $\langle e, t \rangle$, sets of entities, rather than $\langle \langle s, e \rangle, t \rangle$, sets of individual concepts.

(5) a. María busca a un profesor que habla el griego.
Maria seeks prt. a professor who speaks-INDIC the Greek
‘Maria is seeking a professor who speaks Greek.’ (extensional, ‘transparent’, reading: there is a particular professor who speaks Greek that she is looking for)

b. María busca a un profesor que hable el griego.
Maria seeks prt. a professor who speaks-SUBJUNC the Greek
‘Maria is seeking a professor who speaks Greek.’ (intensional, ‘opaque’, reading: any such professor would satisfy her search.)

3. Property-type NP interpretations

While some differences in the possible occurrence of ‘weak’ and ‘strong’ NPs can be accounted for by drawing semantic distinctions within the theory of generalized quantifiers, as in the account described in Lecture 7 ((Milsark 1974, 1977), formal development by (Barwise and Cooper 1981) and by (Keenan 1987)), it has been argued that in some cases, weak NPs are really of “property type” (an intensional variant of type $e \rightarrow t$), rather than generalized quantifiers. Property-type analyses of various “weak NPs” are becoming increasingly common in Western formal semantics, and may have application to some problems in Russian semantics (section 2.3.)

3.1. Zimmermann 1993 on intensional verbs.

Zimmermann (1993) argues that Montague’s analysis of verbs like *seek* (“intensional transitive verbs”, or “opaque verbs”) as taking arguments of type “intension of Generalized Quantifier”, or $\langle s, \langle \langle s, \langle e, t \rangle, t \rangle \rangle \rangle$ is incorrect. He argues that the NP objects of opaque verbs should be semantically interpreted as *properties* (or type $\langle s, \langle e, t \rangle \rangle$.)

3.1.1. The fundamental properties of intensional contexts.

- (1) Caroline found a unicorn. (extensional, unambiguous)
- (2) Caroline sought a unicorn. (intensional, ambiguous)

- Sentences with *seek* are ambiguous between a specific and a non-specific reading (or transparent vs. opaque reading). (1) is unambiguous, (2) is ambiguous.
- On the opaque reading of (2), the existence of a unicorn is not entailed.
- Substitution of extensionally equivalent expressions in an intensional context (on the opaque reading) does not always preserve truth-value. E.g., the extension of *unicorn* is the same as the extension of *13-leaf clover* (both are the empty set in the actual world). Substituting *a thirteen-leaf clover* for *a unicorn* in (1) preserves truth-value. The same substitution in (2) might not.

Examples: *seek, owe, need, lack, prevent, resemble, want, look for, request, demand*.

3.1.2. The classical analysis and its problems.

Quine (1960) argued that *seek* should be decomposed into *try to find*. He argued that intensionality is (in general) the result of embedding under an intensional operator, such as the verb *try*. Within *Caroline try [Caroline find x]*, there are then two places a quantifier phrase could take its scope: the higher clause, giving the transparent reading, and the lower clause, giving the opaque reading.

Montague (1973) argued that the same semantic effect can be achieved with a simpler syntax, if NPs as express Generalized Quantifiers. In argument position, every category gets an intensional operator “ \wedge ” applied to it (i.e. functions apply to the *intensions* of their arguments).

For Montague, the relation between *seek* and *try to find* is captured not by decomposition but by a meaning postulate.

(3) Meaning postulate: $seek'(x, \wedge Q) \rightarrow try'(x, \wedge [Q(\lambda y find'(x, y))])$.

So Montague treats a verb like *seek* as denoting a relation between an individual and an intensional generalized quantifier. The transparent reading results from “quantifying in”.

But there are problems with Quine’s and Montague’s classical analyses. Among other problems, Zimmermann (1993) points out an *overgeneration* problem with Montague’s (and Quine’s) account, in that true quantifier phrases are normally unambiguously “transparent” after intensional transitive verbs like *compare*, *seek*, although they are ambiguous in constructions like *try to find*. Simple indefinites with *a*, on the other hand, are indeed ambiguous with intensional verbs. Compare:

- (4) (a) Arnim compares himself to a pig. (ambiguous)
- (b) Arnim compares himself to each pig. (unambiguously transparent)
- (5) (a) Alain is seeking a comic book. (ambiguous)
- (b) Alain is seeking each comic book. (unambiguous; lacks ambiguity of (c))
- (c) Alain is trying to find each comic book. (ambiguous).

3.1.3. Zimmermann’s alternative account.

Zimmermann argues that we can capture the relevant generalizations once we note that definites and indefinites, which do receive opaque readings with intensional verbs, correspond, in a way he makes precise, to *properties*, type $\langle s, \langle e, t \rangle \rangle$. Zimmermann’s proposal is that a verb like *seek* denotes a relation between an individual and a property. So *seek a unicorn* would be interpreted as (8):

(6) $seek'(\wedge unicorn')$ (where \wedge is Montague’s ‘intension operator’)

This would be a case of NP type-shifting by coercion: *seek* demands a property-type argument, and we know that indefinite NPs easily shift into $\langle s, \langle e, t \rangle \rangle$ readings, as was shown for predicate nominals and the PRED-argument of *consider* in Partee (1986).

For the transparent, or specific, or de re, reading, Zimmermann gives an analysis (details omitted here) involving “quantifying in”, similar to the analysis in Partee (1986) for Edwin Williams’ example “*This house has been every color*”. Zimmermann thus has a solution to the overgeneration problem.

3.2. McNally 1995. “Bare plurals in Spanish are interpreted as properties.”

Bare plurals in Spanish differ from bare plurals in English in several ways; and their distribution and interpretation is not the same as that of overtly indefinite Spanish NPs. McNally (1995) proposes that Spanish bare plurals are uniformly interpreted as **properties**.

It is interesting to compare McNally’s analysis of the Spanish bare plurals as properties with Zimmermann’s analysis of the objects of opaque verbs as properties. In the bare plural analysis, it is the NPs that are specified as being of property type; they combine with ordinary

verbs that take ordinary e-type arguments, and the verbs shift to accommodate these arguments, building in an existential quantifier to bind the e-type argument the verb was looking for: this is a case of *incorporation*. In Zimmermann’s analysis of the opaque verbs, it is the verbs that are semantically special: they demand a property-type argument rather than an e-type argument; so the NPs have to shift to get a property-type meaning in order to occur there, and those that can’t don’t get opaque readings.

It is also interesting to compare McNally’s and other similar analyses along the dimension of independence/non-independence of the NP interpretation, where maximal non-independence means some kind of incorporation. On McNally’s analysis, bare plurals have obligatorily narrowest scope, since the existential quantifier is packed into the shifted meaning of the verb. And the bare plural has no “discourse referent”, which accounts for much of its ‘decreased referentiality’ and non-independence.

Note: there is now quite a lot of literature concerning the possible interpretation of some NPs, especially bare NPs, as denoting properties, or alternatively ‘kinds’; see the following and the references cited in them: (Chierchia 1982, Chierchia 1995, Chierchia 1998, Dayal 2004, Krifka 1995, McNally 1998, Van Geenhoven 1998a); and some of you may have heard the related presentation by Olav Müller-Reichau at FSIM in April.

3.3. Russian Genitive objects of intensional verbs

In the case of the intensional verb *ždat* ‘expect, wait for’ in (34), there may be a shift in verb sense correlated with the shift in the interpretation of the object. The verb selects for the type of its object, and this may be a sort of diathesis shift, with the difference in case marking a difference in semantics: accusative for extensional ‘waiting for’, a relation to a specific individual, and genitive for intensional ‘waiting/hoping for’.

- (34) a. *On ždet podругu.* (Neidle 1988, p.31)
He waits girlfriend-Acc
‘He’s waiting for his girlfriend.’
- b. *On ždet otveta na vopros.*
He waits answer-Gen to question
‘He’s waiting for an answer to the question.’

Neidle (1988, p.31) notes that verbs that lexically govern the genitive in Russian, optionally or obligatorily, “tend to be verbs of desire, aim, request, or achievement.” When there is a choice, Accusative is used for a specific or generic object, indicating that the object is outside the scope of the semantic action of the verb. The Genitive is normally used when object is indefinite (existentially quantified) and within the scope of the verbal “operator”.

As Neidle notes, there can be different ways of characterizing the difference: in terms of relative specificity of the NP object, or in terms of “the specification of the NP either within or outside of the scope of the action of the verb” (Neidle). She would like to say that in either case we are looking at differences in interpretation “associated with differences in the scope of the operation that I will refer to as ‘specification’.” (p.31)

The idea that such differences may reflect type differences relates closely to the work of Zimmermann (1993), discussed above.

There is a connection to the work of van Geenhoven (van Geenhoven 1995, van Geenhoven 1996, Van Geenhoven 1998a, van Geenhoven 1998b), who treats ‘weak’ object NPs in West

Greenlandic as “incorporated to the verb”: they are not fully independent objects, but get an existential quantifier from the verb.

Extension to Gen Neg objects? Problems:

We have considered the hypothesis that there might be something similar between the Acc/Gen alternation with intensional verbs and the Acc/Gen alternation under negation; similar analogies have been drawn by Neidle and are being pursued right now by a graduate student at Hebrew University in Jerusalem, Olga Kagan: she has written an M.A. thesis on the semantics of generic sentences, and is currently writing her Ph.D. thesis on the semantics and syntax of certain Case alternations in Slavic languages, with a special focus on Russian, and a special interest in Case-assignment by opaque verbs

Can we find any good solid parallels in behavior between objects of intensional verbs and Gen Neg objects other than Genitive Case? So far we² have failed. One possible connection, data not clear: What kinds of things permit/ prevent the use of a relative clause with *by* (*kotoraja by* ..., etc.) on an NP direct object? Check with verbs like *ždat* ‘with Acc or Gen, check with negation and Acc or Gen Neg.

I’m unsure about the data and need help here.

- (36) a. # My ždem avtobus (Acc), kotoryj by ...
b. OK: My ždem avtobusa (Gen), kotoryj by ...
- (37) a. ?? On ne znal otvet, kotoryj by ...
b. ?? On ne znal otveta, kotoryj by ...

But that is an example of the kind of data that would be very useful to help establish whether the “NPs as properties” idea could really help capture some deep unity between Genitive with objects of intensional verbs and Gen Neg – and even to help establish whether there is some deep unity to be captured.

4. Modal verbs, conditionals, and accessible possible worlds

4.1. ‘Must’ and ‘may’.

Modal logic, as described in Maribel Romero’s handout and as instantiated in Montague’s IL, has two basic operators, the possibility operator \Diamond (often called “diamond”) and the necessity operator \Box (“box”). The interpretation given in the handout and in the rules for IL treats “logical possibility” and “logical necessity”:

Logical possibility and necessity:

$\Diamond\phi$ is true in a possible world w if there is at least one possible world w' in which ϕ is true. And $\Box\phi$ is true in a possible world w if ϕ is true in every possible world w' .

Modal operators quantify over possible worlds: $\Box\phi$ says, in effect, “ $\forall w \phi(w)$ ” and $\Diamond\phi$ says “ $\exists w \phi(w)$ ”. And like the quantifiers, either one can be defined in terms of the other one plus negation. So if we took \Box as basic, we could define $\Diamond\phi$ as $\neg\Box\neg\phi$. (Or vice versa.)

² “We” refers to NSF-project seminars involving B. Partee, V. Borschev, E. Paducheva, E. Rakhilina, and Y. Testelefs.

When we look at English modal verbs like *must* and *may*, we find that they are similar to logical necessity and possibility, but not exactly the same. Consider “deontic” uses of *must* and *may*, uses that are related to obligations and permissions: what is and isn’t OK to do.

- (6) I must pay my income taxes by April 15.

Does this say that in every possible world, I pay my income taxes by April 15? No, it only says that in every possible world in which I do what the tax laws require, I pay my income taxes by April 15.

Even that is too strong: there are exceptional circumstances in which I am not required to pay by April 15. And that is almost always the case with deontic modals; logical possibility has no exceptions, but deontic possibility generally does. Such exceptions can be expressed in sentences like the following.

- (7) I must pay my income taxes by April 15, but if I file for an extension, I may pay my income taxes between April 15 and October 15.

In the classic works (Kratzer 1977, 1981), Angelika Kratzer showed how the various different senses of English and German modal verbs could be given a unified treatment with some specific parameters that account for their variation under different sorts of modality. One key to her analysis is making use of the *accessibility* relation between worlds, defined formally in Maribel Romero’s handout.

For **deontic possibility and necessity**, we consider at each world w , those worlds w' which are compatible with what the relevant laws or rules in w require.

For **physical possibility and necessity**, we consider at each world w , those worlds w' which are compatible with the laws of physics that hold in w .

For **epistemic possibility and necessity** relative to an agent a , we consider at each world w , those worlds w' which are compatible with what a knows in w .

For **doxastic possibility and necessity** relative to an agent a , we consider at each world w , those worlds w' which are compatible with what a believes in w .

For **metaphysical possibility and necessity**, we consider at each world w , those worlds w' which are compatible with the laws of metaphysics that hold in w . (Different philosophers have different views of what those laws are and how to go about resolving arguments about what they are: that is the subject of *metaphysics*. Emmon Bach (Bach 1986, 1989) has discussed the importance of *natural language metaphysics* for the foundations of semantics; this is similar to the idea of *naivnaja kartina mira* (Apresjan 1986).

Definitions for *must* and *may* on both deontic and epistemic readings are given in Romero’s handout, page 64.

Interesting properties of the different kind of modals have been studied in **model theory**, the study of systematic relationships between logical languages and their models. (Chang and Keisler 1977, Hodges 1993, Hughes and Cresswell 1968) For instance, consider the

following possible axioms of modal logic, which may be appropriate for some kinds of possibility and necessity and not others.

(8) A1. $\Box\phi \rightarrow \phi$.

Is this an axiom we want to adopt for necessity? For logical necessity, yes: if ϕ is true in every possible world, then it must be true in the actual world (or whatever world we are evaluating the formula at.) But for deontic necessity, unfortunately not: not everything which is required by law actually happens. For epistemic necessity, apparently yes: if John knows that ϕ is true, then ϕ is true. (If it weren't, we wouldn't agree that he knows it; that axiom in this case expresses the factivity of the verb *know*.)

The development of possible worlds semantics (Kripke 1959, 1963), (Kanger 1957a, 1957b) and the accompanying development of model theory for modal logic made it possible to show how different competing axiomatizations of modal logic corresponded to different accessibility relations among possible worlds and hence how different competing accounts of the properties of necessity and possibility could all represent different reasonable notions that might correspond to different kinds of necessity and possibility.

The axiom A1 has a direct model-theoretic counterpart in constraints on the accessibility relation. Recall that $\Box\phi$ is true in w if ϕ is true in all w' such that wRw' , i.e. such that w' is accessible from w . It can be proven that axiom A1 holds iff the accessibility relation is reflexive, i.e. every possible world is accessible from itself. So we can say that for logical necessity, the accessibility relation is reflexive. (In fact, for logical necessity, every world is accessible from every other world: the accessibility relation is reflexive, symmetric, and transitive.) And for epistemic necessity also: the actual world must be one of the worlds compatible with everything John knows. But for deontic necessity, the accessibility relation is not reflexive: i.e., a given world w is not always one of the worlds compatible with what the laws in w require.

Let's look at another possible axiom.

(9) A2: $\Diamond\phi \rightarrow \Box\Diamond\phi$. This turns out to hold iff the accessibility relation is symmetric.³

Which kinds of modality seem to conform to A2?

Epistemic modality – no. A2 would say that if it's possible for all I know that ϕ is true, then in every world compatible with what I know, it's possible for all that I would know there that ϕ is true. But that amounts to saying that there's no further evidence I could get that would let me know that ϕ is false. And that's not in general so: in many cases where my knowledge is compatible with ϕ being either true or false, it's clear that in some other worlds compatible with what I know in this world, I would know in those worlds that ϕ is false. For instance, right now in this world, it's possible for all I know that it will rain in Moscow tomorrow (May 25 2005). But there are other possible worlds compatible with what I know now in this one in which I might know for sure that it won't rain in Moscow tomorrow (May 25 2005): in some world w_2 there might be much better weather forecasting methods that we don't have

³ I am citing my own earlier work here (Partee 1988), without rechecking original references on modal logic. Gamut (1991) gives a different axiom for characterizing symmetry of the accessibility relation; but both may be correct – the two axioms may be provably equivalent. But I am not a modal logician myself.

now, where there could be a definite prediction that rain is impossible in Moscow tomorrow, and I know it's reliable, so I can trust it and I know in w_2 that it won't rain tomorrow. (I.e., in all possible worlds compatible with what I know in w_2 , it doesn't rain in Moscow on May 25 2005.)

Deontic modality – also no. If it's permitted by the laws of w_1 , that doesn't mean that it's required by the laws w_1 of that it be permitted.

Logical modality – yes. If ϕ is possible, then it's necessarily possible, since every world is accessible from every other world, and 'possible ϕ ' says that ϕ is true in at least one world.

One more example:

(10) A3: $\Box\phi \rightarrow \Box\Box\phi$. This axiom holds iff the accessibility relation is transitive.

Deontic modality -- probably no. **Epistemic modality** – philosophers argue about this one. If you know that ϕ , do you know that you know that ϕ ? Usually; but I think that dogs may know things but not know that they know things. **Logical modality** – definitely yes.

About exceptions: Not discussing here, but Kratzer also proposed a nice way to handle them, by setting up an ordering among accessible worlds, and making the quantification over accessible worlds sensitive to this ordering as well. In the deontic case, this means that we consider different alternative worlds not just as in conformity with what the law requires or not, but as *more* or *less* in conformity with what the law requires. That helps explain why it's not inconsistent to have laws that tell what to must be done when other laws are broken.

4.2. Counterfactual conditionals.

Another intensional domain where possible worlds semantics has been very fruitful is the analysis of so-called *counterfactual conditionals* (really, a class which Jespersen more appropriately called *imaginative conditionals*, because it is not really always required that the antecedent be false, although that is the case most typically discussed.) They can be characterized syntactically as *subjunctive conditionals*; I think they correspond quite closely, perhaps exactly, to Russian conditionals with *esli by*. Let us begin with some examples to distinguish plain (indicative) conditionals from counterfactual (subjunctive) conditionals. Here are some facts in the actual world: Morriss Partee was born in 1967. David Partee was born in 1969. Joel Partee was born in 1970.

- (11)
- a. If David Partee was born in 1968, he is older than Morriss Partee is.
 - b. If David Partee was born in 1966, he is older than Morriss Partee is.
 - c. If David Partee had been born in 1968, he would be older than Morriss Partee is.
 - d. If David Partee had been born in 1966, he would be older than Morriss Partee is.

The two indicative conditionals (11a-b) are both true simply because they both have false antecedents. But of the two subjunctive conditionals, (11c-d), one is true and one is false. For them, we don't just consider the facts in the actual world: we look at what the world *would have been like* if David had been born in a different year – that is, we look at different possible worlds. And we see that since Morriss was born in 1967 (we keep that fixed: note the indicative *than Morriss is* in the comparative), then if David had been born in 1968 he would still be younger than Morriss, but if he had been born in 1966 he would be older. So (11c) is false, and (11d) is true.

More examples of subjunctive conditionals: here is a pair from Chierchia and McConnell-Ginet (1990); as they point out, we generally judge (12a) false, and (12b) true. Again both have a false antecedent, so by the logic of plain conditionals, both would be true.

- (12) a. If Proust had taken a cruise on the *Titanic*, the *Titanic* would not have sunk.
b. If Proust had taken a cruise on the *Titanic*, *Remembrance of Things Past* would not have been completed, and literature would have suffered a great loss.

Philosophers of language and logicians had struggled with the problem of the logic of subjunctive conditionals for many years before Stalnaker and Lewis came up with their now-classic possible-worlds solutions (Lewis 1973, Stalnaker 1968) (slightly different in ways we will ignore). One of the difficult puzzles was the following. Normally it seems reasonable to accept, for any kind of implication or inference, an axiom that says “if $A \rightarrow C$ is true, then $(A \ \& \ B) \rightarrow C$ is true” – this is a principle called “Strengthening the Antecedent”. But for subjunctive conditionals, the principle seems to fail: we may judge (a) true, but (b) false. And to make life even more complicated, we may judge (c) true again, and one can keep going like that indefinitely, constructing a chain of alternating true-false examples.

- (13) a. If I struck this match, it would light.
b. If I struck this match and the match were wet, it would light.
c. If I struck this match and the match were wet and the match had been coated with paraffin, it would light.

The Stalnaker-Lewis solution makes use of possible worlds and an ordering of relative similarity among them.

- (14) The conditional “If ϕ were the case, then ψ would be the case” is true in w iff:
in the worlds w' where ϕ is true that are closest to w , ψ is true.

So for example, for examples ((12a-b), we look at the worlds that are most similar to the actual world except that Proust takes a cruise on the *Titanic*. And if we assume no differences other than those immediately connected to Proust being on the *Titanic* at that time, we will agree that the *Titanic* wouldn’t be prevented from sinking, but Proust would most likely have died and his novel wouldn’t have been finished. And in the case of the examples in (13), we can see that each successive antecedent *if*-clause requires us to look at worlds that are successively ‘farther away’ from the actual world, since in the actual world the match is not wet, not coated with paraffin, etc.

Similar notions of similarity among worlds are the key to the evaluation of ‘exceptions’ to statements of modal necessity, such as that illustrated in sentence (7) above.

Other domains where possible worlds have helped to bring important improvements in semantic analysis include intensional adjectives and adverbs, generic, habitual, and dispositional sentences, “dispositional affixes” like *-able* and others (*washable*, *forgetful*), constructions with infinitive complements and propositional complements, and many others. Further, as Montague showed, the semantics of temporal operators like “PAST” and “FUTURE” has much in common with the semantics of modal operators, and the two frequently interact. Portner (1992, 1997) gave a nice analysis of the semantics of embedded infinitivals that accounts for the fact that they are normally interpreted as involving possible worlds that “branch off” from the world of evaluation in the future but are identical to the world of evaluation up until the temporal point at which the matrix clause is interpreted as holding. This helps explain such differences as that between (15a) and (15b), and helps explain why (15c) cannot have the interpretation of (15b).

- (15) a. John wants to be rich. (says something about a wish for the future.)
b. John wishes that he were rich. (a ‘counterfactual’ wish – wishing that the present were different from what it is.)
c. John wishes to be rich. (Can only mean the same as a, not b.)

There is undoubtedly much more work to be done to uncover the way our *naivnaja kartina mira* structures alternative possible worlds and alternative possible situations, and the best way to explore this domain is undoubtedly to find out more about the semantics of modal and intensional constructions in natural languages – how much is universal, how much can vary, and how?

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