Questions About Model Theory, Proof Theory, and Semantically Flavored Syntactic Features

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Semantics plays a role in grammar in at least three guises. (A) Linguists seek to account for speakers' knowledge of what linguistic expressions mean. This goal is typically achieved by assigning a model theoretic interpretation[1] in a compositional fashion. For example, *No whale flies* is true if and only if the intersection of the sets of whales and fliers is empty in the model. (B) Linguists seek to account for the ability of speakers to make various inferences based on semantic knowledge. For example, *No whale flies* entails *No blue whale flies* and *No whale flies high*. (C) The well-formedness of a variety of syntactic constructions depends on morpho-syntactic features with a semantic flavor. For example, *Under no circumstances would a whale fly* is grammatical, whereas *Under some circumstances would a whale fly* is not, corresponding to the decreasing vs. increasing features of the preposed phrases.

It is usually assumed that once a compositional model theoretic interpretation is assigned to all expressions, its fruits can be freely enjoyed by inferencing and syntax. What place might proof theory have in this picture? This paper attempts to raise questions rather than offer a thesis. The first part is an overview and the second part elaborates on some empirical aspects of semantically flavored syntactic features.

1. Model theory and proof theory

Two approaches to semantics are the model theoretic and the proof theoretic ones. Using a familiar example, consider the model theoretic and the proof theoretic faces of propositional logic. The interpretation of the connectives $\wedge$,$\vee$, and $\neg$ in terms of truth tables is the simplest kind of model theoretic semantics. It also determines relations between formulae. For example, $\neg p$ is a logical consequence of $\neg(p\vee q)$ because all the ways of assigning values to p and q that make $\neg(p\vee q)$ true also make $\neg p$ true. Thus the inference is said to be semantically valid (notated as $\models$). Compare this with how the propositional calculus approaches the same inference. It offers a set of transition steps, the de Morgan law $\neg(p\vee q)= \neg p\wedge\neg q$ among them, with which the string of symbols $\neg p$ can be derived from the string

[1] There may be a discrepancy in the use of the term "semantics" between formal semanticists and philosophers. The former do not concern themselves with questions of reference and, in general, the relationship between expressions and the world out there; the entities in the models are abstract and linguistically/mathematically motivated.

$\neg(p\vee q)$. This demonstrates the so-called syntactic validity of the inference (notated as |-). A calculus is sound if whatever it derives is true in the intended models ($\phi \vdash \psi$ only if $\phi \models \psi$); complete if it can derive whatever is true in the models ($\phi \vdash \psi$ whenever $\phi \models \psi$); and decidable if an algorithm can effectively determine whether $\phi \vdash \psi$ holds. The propositional calculus is sound, complete, and decidable; the first order predicate calculus is sound and complete. More complex calculi have at most generalized completeness.

As the term `syntactic validity' indicates, proof theory involves symbol manipulation. Nevertheless, given soundness and (some degree of) completeness, a calculus deserves the name `proof theoretic semantics' in that it cashes out model theoretic semantic relations in its own syntactic terms, rather than concerning itself with the plain well-formedness of expressions, e.g., whether $(p\wedge)$ is well-formed.[2]

On this view, model theory has primacy over proof theory. A language may be defined or described perfectly well without providing a calculus (thus, a logic) for it, but a calculus is of distinctly limited interest without a class of models with respect to which it is known to be sound and (to some degree) complete.

It seems fair to say that (a large portion of)[3] mainstream formal semantics as practiced by linguists is exclusively model theoretic. As I understand it, the main goal is to elucidate the meanings of expressions in a compositional fashion, and to do that in a way that offers an insight into natural language metaphysics (Bach 1989) and uncovers universals of the syntax/semantics interface [4]. Non-linguists sometimes regard the compositional interpretation of natural language expressions either as impossible or just a simple exercise. In contrast, linguists have come to think of it as a huge but rewarding empirical enterprise. The fact that the insights accumulated over the past decades have been obtained by investigating denotation conditions[5] plays an immense role in linguists' acceptance of and adherence to the model theoretic approach.

The view that model theory is not only necessary but also the primary source of insights is not the linguist's invention. For example, in the Gamut textbook's chapter on "Arguments and Inferences", the authors--here, probably, Johan van Benthem and/or Dick de Jongh—put forward that "[S]emantic methods tend to give one a better understanding" but,

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[2] Different calculi can be very different as regards intuitiveness and efficiency. This paper abstracts away from such differences. Sometimes natural deduction will be used to illustrate a point, but only because it is more widely known than sequent calculi or other tools.

[3] The qualification is inserted because I am not quite sure of the position of the extensive work on implicatures, inspired by Grice. As far as I can see, the techniques are clearly model theoretic but the goals may or may not be.

[4] Conservativity, a property of determiners or, more generally, of expressions denoting relations between sets, may be the best established example. Det is conservative iff $Det(A)(B) = Det(A)(A\cap B)$.

[5] I am carefully avoiding the term `truth (conditions)', because only a fraction of natural language sentences and subsentential expressions can be said to be true or false to begin with, and also because it is immaterial from this perspective whether sentences are associated with truth values, situations, events, or something else.

they go on, "[they are] based on universal quantification over that mysterious totality, the class of all models (there are infinitely many models, and models themselves can be infinitely large). The notion of meaning that we use in the syntactic approach is more instrumental: the meaning of some part of the sentence lies in the conclusions which, because precisely that part appears at precisely that place, can be drawn from the sentence […]."

This observation is nothing new, of course, but the idea that our way of doing semantics is both insightful and computationally (psychologically) unrealistic has failed to intrigue formal semanticists into action.[6] Why? There are various, to my mind respectable, possibilities. (i) Given that the field is young and still in the process of identifying the main facts it should account for, we are going for the insight as opposed to the potential of computational / psychological reality. (ii) We don't care about psychological reality and only study language in the abstract. (iii) We do care about potential psychological reality but are content to separate the elucidation of meaning (model theory) from the account of inferencing (proof theory). But if the machineries of model theory and proof theory are sufficiently different, option (iii) may end up with a picture where speakers cannot know what sentences mean, so to speak, only how to draw inferences from them. Is that the correct picture? Perhaps we could have our cake and eat it too. Or have an altogether better cake if we cared to modify the recipe. It seems that a better understanding of the choice we made and of other choices that we might make would be useful. The present paper wishes to highlight this need and to elicit comments from linguists and from the neighboring fields.

In my initial attempt to reduce my ignorance, I seem to have identified three interestingly different proof theoretic perspectives on semantics.[7]

Infinity appears to be the most typical complaint against model theoretic semantics. [8] Indeed, finite systems may not literally house and manipulate an infinite set of infinite models, but this need not be a knockdown argument against the model theoretic approach. Infinity is necessary to capture the uncertainty as to what model, and what part of that model,

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[6] Clearly, we are talking about proof theory offering the abstract possibility of psychological reality; there is no claim to the effect that people have, say, Natural Deduction machines in their heads.

[7] Proof theoretic approaches to natural language using categorial type logics have a rich tradition (Moortgat 1997, 2002; Oehrle 2003). But as far as I can see, the main focus has been on the syntax of natural languages. The central interpretive concern is limited to the Curry-Howard isomorphism between types and lambda terms, i.e. to the interpretive effects of syntactic assembly. Aspects of meaning that go beyond type specification are not studied with any systematicity. Thus the actual results so far bear only on some of the issues formal semanticists tend to be interested in.

[8] Chomsky has often declared that semantics has no place within grammar. One might read this as a rejection of infinite models and as a commitment to proof theory, but it seems to me that what Chomsky strives to reject is incorporating (links to) the real world. If so, then what formal semanticists do with abstract models may be fine, as long as it is regarded as part of syntax. Chomsky's exchange with Larson at the "Happy Golden Anniversary, Generative Syntax" workshop (MIT, July 16, 2005) seems to confirm this. In other words, the mentalistic view of language may entail an answer to the model theory vs. proof theory dilemma, but it is not my impression that Chomsky's actual statements are about this issue.

we are talking about, but capturing this uncertainty need not belong to the object language. At the object language level infinity might be traded for partiality, retaining the strategy of assigning denotation conditions to expressions. Barwise and Perry 1983, Muskens 1995, and Kamp and Reyle 1993, 1996 come to mind. Denotation conditions, not infinity, are at the heart of the linguist's attraction to model theory; they could be disentangled.

A very interesting recent proposal of this sort is van Lambalgen and Hamm 2005. Here an event calculus is combined with minimal models in which events that the scenario of the given activity does not require to occur are assumed not to occur and enlargement of the model leads to nonmonotonic progression. What makes the proposal especially interesting is the fact that it puts to linguistic use a program for semantics where the sense of an expression is the algorithm that allows one to compute the denotation of the expression. L&H submit that only a computational notion of meaning is compatible with the results of psycholinguistics, but (drawing from Kamp's and Steedman's work on tense) the representations their theory computes are not alien to the denotational semantic intuition linguists have found insightful to work with.

A second relevant approach, Natural Logic, bears out the slogan that proof theory "syntacticizes semantics", not only in the sense that it manipulates representations, but also in the sense that it lives off of the actual syntactic representations of expressions. It uses linguistic structures[9], as opposed to models or an auxiliary logical language, as the vehicle of inference. The literature contains a collection of small subsystems that are individually sound and complete in terms of the standard models. The techniques are fairly diverse. Johan van Benthem's Monotonicity Calculus, explored further by Victor Sánchez-Valencia, tags all items for monotonicity and for polarity position, and computes the increasing/decreasing inferential status of any expression in tandem with the categorial grammatical derivation. Larry Moss presents a syllogistic logic with quantifiers, notably including *most*, which is not first order definable. Yoad Winter handles inferences with restrictive modification, monotonicity, and quantifier scope, exploiting insights from generalized quantifier theory.

If proof theory syntacticizes semantics, it may be of particular interest to pay attention to semantic properties that natural language already singles out as syntactically relevant. I will dub these semantically flavored syntactic features. It turns out that such features are quite pervasive, and generative syntax uses them to condition concatenation (merger) and movement. The so-called negative inversion construction of English is an example.

(1) *Under no/few circumstances would a whale fly.*
(2) **Under some/most circumstances would a whale fly.*

(1) is acceptable, (2) is not, although it does not seem incoherent. The generalization is that

[9] That is, strings together with their syntactic and possibly intonational analyses. This is a straightforward response to the "misleading form" objection to Natural Logic.

the initial position accepts an adjunct only if it is (roughly) decreasing.[10] One way to implement this is to assume that whenever the question of filling this position arises in a syntactic derivation, the compositional model theoretic interpretation of the adjunct is inspected for decreasingness. This is what semanticists would do by default. Another implementation is to assume that certain adjuncts have a purely syntactic feature [de]; the set of expressions with [de] may substantially overlap or even coincide with those whose denotations are decreasing, but this fact has no place in the theory. This is what syntacticians would do by default. In contrast, Stabler (1997) proposes that [de] is a properly syntactic feature but, in addition to licensing syntactic operations like negative inversion, it features in the proof theoretic component and speakers use it to draw inferences. The second half of this paper will illustrate the phenomenon of semantically flavored syntactic features in some detail and ask how they might be used in the proof theoretic component.

A third approach rejects the notion that inferences should play second fiddle to denotations. As Kahle and Schroeder-Heister (2004) put it,[11] "Proof-theoretic semantics proceeds the other way round, assigning proofs or deductions an autonomous semantic role from the very onset, rather than explaining this role in terms of truth transmission. In proof-theoretic semantics, proofs are not merely treated as syntactic objects as in Hilbert's formalist philosophy of mathematics, but as entities in terms of which meaning and logical consequence can be explained."[12] In a similar spirit, Moss (2005) wonders, "If one is seriously interested in entailment, why not study it axiomatically instead of building models? In particular, if one has a complete proof system, why not declare it to *be* the semantics? Indeed, why should semantics be founded on model theory rather than proof theory?"

Given the absence of pertinent literature, I am not in a position to judge how a semantics founded on proof theory would fare for natural language. In addition to a possibly major conceptual shift, I suspect that it may involve shifts in the detailed intuitions captured. To use a simple example, consider the model theoretic and the natural deduction treatments of the propositional connectives. The two ways of explicating conjunction and disjunction amount to the same thing indeed: if you know the one you can immediately guess the other. Not so with classical negation. The model theoretic definition is in one step: $\neg p$ is true if and only if p is not true. In contrast, natural deduction obtains the same result in three steps. First, elimination and introduction rules for $\neg$ yield a notion of negation as in minimal logic. Then the rule Ex Falso Sequitur Quodlibet is added to obtain intuitionistic negation, and finally

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[10] This seems to be the same property as the one involved in the licensing of negative polarity items like *ever*. Given $A \leq B$, a function f is monotonically increasing (upward entailing) iff $f(A) \leq f(B)$, and decreasing (downward entailing) iff $f(A) \geq f(B)$. See Ladusaw 1980, von Fintel 1999.

[11] The introduction to the forthcoming special issue of *Synthese* on proof theoretic semantics is posted on the internet, but it has proved impossible to get hold of any of the papers.

[12] Perhaps Horwich (2005) has something partially similar in mind when, in the context of deflationism, he proposes to formulate the semantics in terms of rules of use as opposed to truth conditions (model theory) both in logical and in natural languages.

Double Negation Cancellation to obtain classical negation. While it may be a matter of debate which explication is more insightful, it seems clear that the two are intuitively not the same, even though eventually they deliver the same result.

So, some general questions arise, for the global approaches as well as for the particular variants.

Proponents of proof theoretic methods seem confident that only their approach, not the model theoretic one, can be integrated with the rest of cognitive science. Is that correct? If yes, what is the crux of the matter -- finite representations or inferential character?[13]

Do model theoretic and proof theoretic semantics differ as to what general conception of language they fit with? Would there be gains or losses in domains not considered above?

What are the prospects of extending the proof theoretic approach to intensional phenomena, presupposition, and implicatures?

What kind of compositionality would proof theoretic approaches afford? Although it has sometimes been suggested that any effective procedure that computes meanings will do, I believe that there is an important consideration that suggests that we must be more particular. Whatever one might think of the specific theories generative grammar has come up with over the past decades, I believe it has been demonstrated beyond any reasonable doubt that natural languages, while superficially wildly different, exhibit very detailed and thoroughgoing structural similarities; in other words, that "universal grammar" is not merely a wishful thought. Therefore no theory incapable of accounting for the unity behind the superficial variation stands a chance to be an even remotely valid theory of natural language. Now, cross-linguistic variation in syntax is to some extent parallelled by cross-linguistic variation in interpretation.

Two simple examples. (i) Given the right predicate, bare plurals in English and German may have an existential or a generic reading:

(3) *Professors are sick.*
`There are professors stricken with illness'
`Professors in general are disgusting'

But it is well-known that in many other languages, Romance languages among them, one or both interpretations may be unavailable. (ii) The interaction of negation with disjunction and conjunction in English and German straightforwardly bears out the de Morgan laws:

(4) John didn't study flute or accounting.
`neither'

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[13] Referring to mathematical results that the set of first order quantifiers is not identifiable in the limit from examples, Stabler 2005 points out that they might be learnable given inferential evidence.

(5) *John didn't study flute and accounting.*
`not both'

In many other languages, Russian, Italian, Japanese, and Hungarian among them, the above interpretations are missing. The literal counterparts of (4) mean exclusively `One or the other he didn't study' and the literal counterparts of (5) mean exclusively `He studied neither one'.

Given such variation, it does not suffice to provide some effective procedure that delivers the correct interpretations for the constructions of the individual languages; what is needed is a compositional analysis that accounts for exactly how languages differ.[14] Without that, human languages will appear to be incommensurable.

2. Semantically flavored syntactic features

Stabler 1997 proposes that natural language syntax may be sensitive to semantic properties precisely because its semantics is proof theoretical in nature and those particular properties play a role in this proof theory.[15] If this is correct, then syntax is a "window on the format of semantics". The goal of this section is to illustrate the phenomenon of semantically flavored syntactic features.

Many recent versions of generative syntax rely extensively on functional heads and features. Functional heads are overt or covert elements that embody, assign, or "check" features carried by lexical items or phrases; many aspects of syntactic well-formedness depend on this. If one inspects the inventory of features, it turns out that the overwhelming majority of them are more or less semantic.[16] Some fairly standard examples are [wh] (i.e. interrogative), [topic], [focus], [negative], [agent], [number], [telic], [evidential], and so on. But while the semantic intuition is evident, the exact semantic content of the features is often not investigated. ("We will assume that phrases that move into this position carry some feature F, call it [topic].") On the other hand, when the precise content is known, it is often argued that the (un)acceptability of the given construction is actually a matter of semantics or pragmatics, not syntax. For example, *There's every crumpled tissue in my pocket* is a pretty awful sentence. But while it may be possible to rule it out by requiring determiners that participate in the *there*-construction to have a feature [intersective][17], which *every* lacks, it is observed that the above sentence does not express anything any coherent or useful, and

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[14] Chierchia 1998 and Szabolcsi and Haddican 2004 are such attempts.
[15] This formulation is somewhat stronger than Stabler's text but it is, I believe, in keeping with Stabler's views and intentions.
[16] The straightforward exceptions are case features (nominative, accusative, …) and gender agreement features in a language like French or German.
[17] This is not quite the right property but it suffices for illustration. Det is intersective iff the truth of Det(A)(B) depends only on the cardinality of $[[A]]\cap[[B]]$.

therefore it is possible that the place to rule it out is semantics or pragmatics (Keenan 2003). How to proceed in such cases is a very interesting question but, I believe, it should not cast doubt on the claim that syntactic well-formedness is often conditioned by semantic properties. English negative inversion is a good example, because it involves a difference in surface word order and because the non-inverted order is also perfect: *A whale would fly under few circumstances*. Such straightforward and theory-neutrally syntactic examples are fairly rare in English. I would like to make the case for the pervasiveness of semantically flavored syntactic features and will use data from Hungarian.

In "unmarked" cases, constituent order in English is determined by grammatical function: subject precedes direct object, etc. It is neither determined nor significantly constrained by what kind of noun phrases fulfil those functions. As regards scope, the subject may always scope over the direct object; whether the direct object may scope over the subject is constrained by quantifier type, e.g.

(6) *Few men saw every film.* few>every, every>few
(7) *Every man saw few films.* every>few, *few>every

Most treatments of scope in English do not capture the above contrast, because they employ semantically blind rules of scope assignment. But even if a particular treatment were to capture it, it takes fairly theory dependent arguments to decide whether the phenomenon is a syntactic or a semantic one. Consideration of Hungarian is interesting here, because this language disambiguates scope in its surface word order. In this way, if semantic distinctions play a role in the scope phenomenology, we have fairly theory neutral evidence that in at least one language, these distinctions are "syntacticized". Depending on one's views about universal grammar one may draw a stronger conclusion.[18]

Since the early 1980's Hungarian has come to be known as a language that wears its semantics on its syntactic sleeve. The observation is most readily demonstrated by considering the preverbal field of the sentence. It has two crucial properties: the left-to-right order of operators corresponds to their scopal order, and the order in which operators line up is not determined by their grammatical functions but, rather, by what semantic classes they belong to.

The examples in (8) illustrate these points. The linearly first quantifier invariably scopes over the linearly second one, and the quantifier whose determiner is *minden* \`every' invariably precedes the one whose determiner is *kevés* \`few', irrespective of which of the two

[18] Beghelli and Stowell 1997 actually proposed a Logical Form syntax for English that is fairly similar to what Hungarian exhibits on the surface. Kayne 1998 argues that there is no need to postulate Logical Form representations, because surface structure is more complex than meets the eye.

is the subject and which is the direct object.[19]

(8) a. *Minden ember kevés filmet látott.*
every man-nom few film-acc saw
\`Every man saw few films: every $_{\text{subject}}$ > few$_{\text{object}}$'

b. *Minden filmet kevés ember látott.*
every film-acc few man-nom saw
\`Few men saw every film: every $_{\text{object}}$ > few $_{\text{subject}}$'

c. **Kevés ember minden filmet látott.*
few men-nom every film-acc saw

d. **Kevés filmet minden ember látott.*
few film-acc every man-nom saw

Three main word order positions can be distinguished in the preverbal field, to be labelled the topic, the distributive, and the counting quantifier (counter) positions. The table in (9) lists some of their representative inhabitants. The topic and the distributive positions can be multiply filled.

(9)	**Topic(s)**	**>**	**Distributive(s)**	**>**	**Counter**	**>**	**Verb**
	Jancsó Miklós		*minden film*		*kevés film*		
	\`Miklos Jancso'		\`every film'		\`few films'		
	a film, a filmek		*több, mint hat film*		*több, mint hat film*		
	\`the film', \`the films'		\`more than six films'		\`more than six films'		
	hat film, a hat film				*pontosan hat film*		
	\`six films', \`the six films'				\`exactly six films'		

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[19] The \`few > every' scopal order is expressible only if the universal occurs in the postverbal field of the sentence, as in (i).

(i) *a.* *Kevés ember látott minden filmet.*
few men-nom saw every film-acc
\`Few men saw every film: few $_{\text{subject}}$ > every $_{\text{object}}$'
b. *Kevés filmet látott minden ember.*
few films-acc saw every man-nom
\`Every man saw few films: few $_{\text{object}}$ > every $_{\text{subject}}$'

The order within the postverbal field and the detailed interaction of preverbal and postverbal quantifiers is immaterial to us, so from now on the postverbal field will be ignored. See Brody and Szabolcsi 2003 for discussion.

Each position has two semantic aspects: what kind of expressions it hosts and how they are interpreted there. The two aspects are related. Only expressions denoting monotonically increasing generalized quantifiers (GQs) occur in the topic and the distributive positions. I have proposed that this constraint is due to the fact that interpretation in these positions involves existential quantification over pluralities (groups or sets); [20] in the absence of an explicit maximality condition such quantification would go wrong with expressions that set an upper bound. Topics enter the sentence with a group interpretation and undergo either collective or distributive predication; in contrast, expressions in the distributive position invariably supply the sorting key set of a distributive operator. The third, immediately preverbal position is unconstrained with respect to monotonicity and its inhabitants are construed as performing a counting operation. Depending on the predicate, they may count the elements of a set or the atoms of a group.[21]

These observations may be summarized as in (10). The ⇒ symbol is to be read as material implication or inclusion. The first and the third columns are suggestive of some correlation between order and interpretive specificity. However, there is no inclusion relation between the sets of expressions serving as topics, distributives, and counters, because each position imposes an additional distinctive feature and thus requires its inhabitants to be able to carry it. For example, *minden film* `every film' denotes a generalized quantifier, but cannot be construed as performing a counting operation and does not occur in the counter position.

(10)	**Linear / scope order of position**	**Distinctive feature in position**		**Denotational prerequisite for occurrence in position**
	leftmost / widest	topic	⇒	GQ, increasing, group
	∨			⇓
	mid / mid	distributive key	⇒	GQ, increasing
	∨			⇓
	rightmost / narrowest	counter	⇒	GQ

[20] Szabolcsi 1997 argued in detail that expressions in the topic and distributive positions, in contrast to counters, introduce discourse referents: they support cross-sentential anaphora and may have extra-wide existential import. The literature standardly handles this by existential quantification over pluralities or over choice functions yielding pluralities. It was also suggested that there is a difference in verification procedures: topics and distributives employ a "look-up" strategy and counters a "compute" strategy.

[21] Thus, when the same quantifier may occur in either the distributive or the counter position, its interpretation varies with the position. For example, the sentence *More than six estates surround the lake* has two counterparts in Hungarian, conveniently distinguished by the position of a verbal prefix. When the quantifier is in the distributive position, the sentence says that there is a particular set of more than six estates each element of which surrounds the lake (in concentric circles). When the quantifier is in the counter position, the sentence merely specifies the number of estates involved in surrounding the lake, and the surrounding itself may be either distributive or collective.

Let us now add focus and negation to this picture. Contrastive focus in Hungarian does not only bear stress but is also immediately preverbal.[22] Thus foci compete with counters and do not co-occur. But foci and counters are interpreted differently, see (11),[23] and they are preceded by different operators, see (12). (12a) highlights the existence of two semantically identical sentential negations that may co-occur. The one preceding the focussed phrase will be labelled high negation (hi-neg) and the one following it low negation (lo-neg).

(11) a. Focus
A film (nem) lesz sikeres.
the film (not) will-be successful
`It is the film that will (not) be successful [and not the musical]'
b. Counter
Kevés film (nem) lesz sikeres.
few films (not) will-be successful
`Few films will (not) be successful' *vs.* *`It is few films that will (not) be successful'

(12) a. Focus
Nem a film (nem) lesz sikeres.
not the film (not) will-be successful
`It is not the film that will (not) be successful [but the musical]'
b. Counter
**Nem kevés film (nem) lesz sikeres.* [24]
not few films (not) will-be successful

The addition of focus and negation to the picture lays bare the fact that the set of syntactic positions is not linearly ordered, contrary to what is generally assumed in the literature but in agreement with Nilsen (2001, 2003). The fact that foci and counters do not

[22] More precisely, foci and counters are immediately preverbal in that they cannot be separated from the verb by a full phrase, although they can be separated from it by negation.
[23] The phrases that can be focused in toto are the same group denoters that occur as topics. Szabolcsi 1994 argued that the reason is that the identificational interpretation of focus, paraphrased in (11) with *it*-clefts, is only applicable to group denoters.
[24] The string in (12b) is acceptable when the first negation is determiner-internal and *nem kevés* `not few' has an interpretation comparable to that of *nonnullus* `a certain amount of, not a little; a number of, not a few; some men' (Oxford Latin Dictionary). *Nem kevés film* is an upward monotonic quantifier that exhibits the same dual behavior as `more than six films'. Likewise, the string in (12b) is acceptable if just the determiner *kevés* is contrastive; in that case *kevés film* behaves not as a counter but as a phrase that inherits a focus feature from a subconstituent. The * in (12b) indicates that the sentence is not acceptable with a structure that is parallel to that of (12a): the counter position per se cannot be preceded by high negation (among other operators not examined here).

co-occur points to this conclusion. The same conclusion is reinforced by the observation that different quantifiers exhibit different scope restrictions with respect to negation. Specifically, universals like *minden film* `every film’ cannot scope immediately over clause-mate negation. A universal that has negation in its immediate scope takes the shape of a so-called negative concord item (*semelyik film*, lit. `no film’), and negative concord items in turn must scope immediately over negation or another negative concord item.[25] Now expressions that must and expressions that must not scope immediately over negation cannot be linearly ordered with respect to each other.

In sum, a partially ordered set of syntactic categories is called for; see (13) for a proposal. The ordering relation in this set corresponds to the derivability relation in a particular multimodal categorial type logic of residuation with unary operators, but this fact does not play a role in the present discussion.[26] The derivability relation between the categories $A_i \rightarrow A_j$ corresponds to an inclusion relation $A_i' \subseteq A_j'$ between the sets of expressions that belong to those categories.[27] See Bernardi and Szabolcsi 2005.

In (13) each S_i is a subcategory of the syntactic category Sentence. S1 is the category of sentences with the verb in initial position. For simplicity, quantifiers are represented as sentential operators. The curved arrows (red in the file) represent the categories of such operators, pointing from their argument category to their value category. An expression whose argument category is S_i can apply to (be quantified into) any sentence with category S_k, where $S_i \geq S_k$. In other words, OP_a can scope over (and in Hungarian, precede) OP_b iff $val_b \leq arg_a$.

Low negation maps S1 to S1*, and high negation S4 to S4*. S2 is ordered above both S1 and S1*, and S3 above both S4 and S4*. Expressions that do not care whether or not they scope directly above negation have their argument categories on the S2--S3--S9--S10 track. Those that must not scope directly above negation have their argument categories on the S1--S4--S8 track, and those that must scope directly above negation or another operator of their own kind (negative concord items) on the S4*--S8* track. The former distributives are now divided into the <S9, S8> and the <S8, S8> subclasses. Foci and counters have the same argument category but different value categories, <S2,S4> and <S2,S8>. This same partially ordered set of categories accommodates various further operators that the present paper does not discuss; that is why it is more “spread out” that what might seem necessary.

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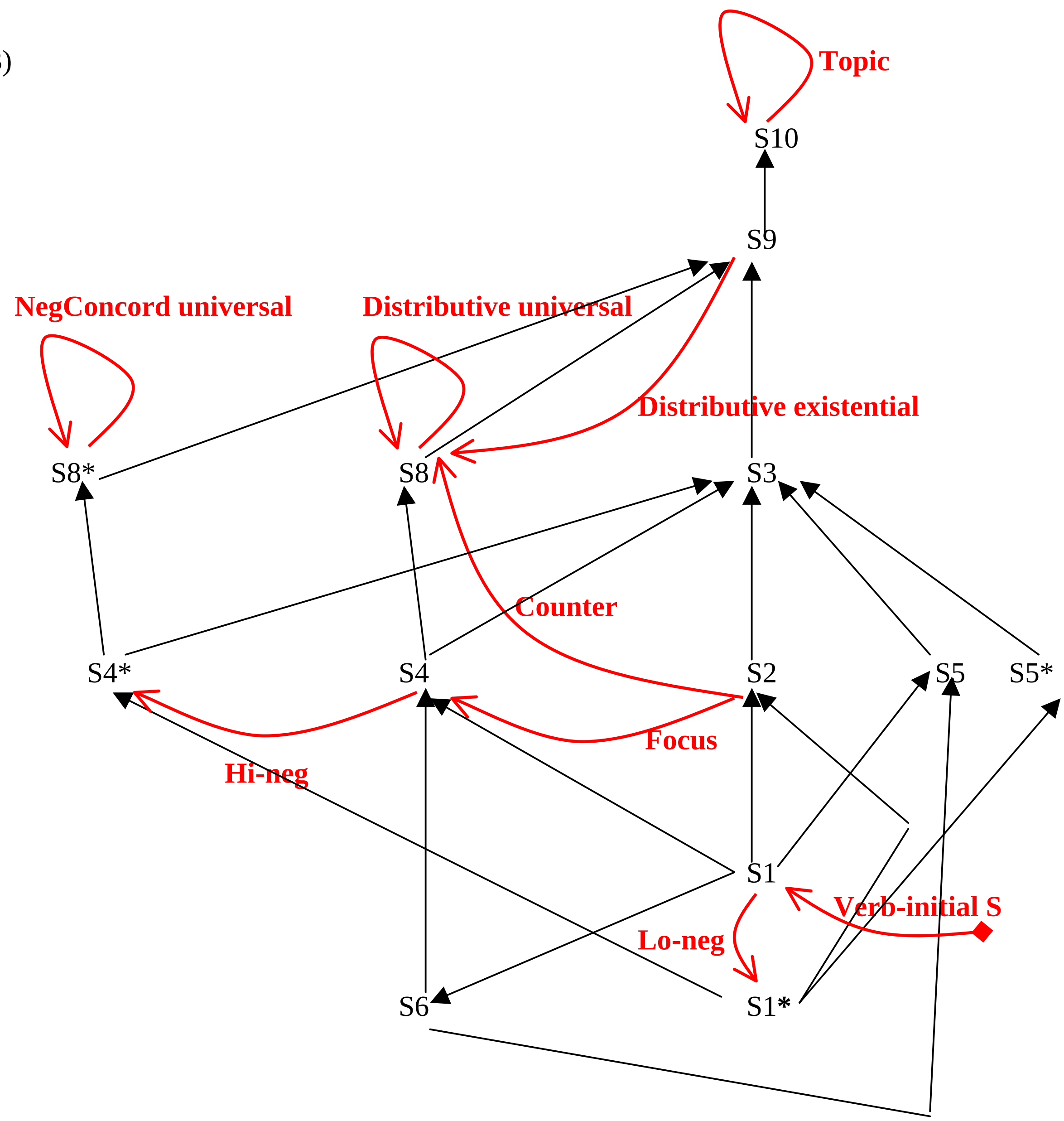
[25] The data are the same as in Modern Greek, and I am proposing the same analysis as Giannakidou 2000. It is interesting to note, though, that the inability of ordinary universals to scope immediately over negation is not contingent on the language having negative concord: Norwegian has the former but not the latter property (Nilsen 2001, 2003).

[26] The operators # and @ form a residuated pair iff $\#@A \rightarrow A$ iff $A \rightarrow @\#A$. In (8), S1is $\Diamond\Box A$, S2 is A, and S3 is $\Box\Diamond A$. (13) also exploits multimodality. S1 is $\Diamond\Box S$, and S1* is $\blacklozenge\blacksquare S$; both derive S.

[27] This is more intuitive than the standard interpretation in terms of Kripke frames with words for worlds.

(13)



In sum, we have seen that semantic properties can be directly relevant for syntactic well-formedness and obtained a small inventory of such properties, or features: increasing/decreasing, negation, set or group denoter, topic, focus, counter, distributive, etc. If natural language singles out these properties as syntactically relevant, they can be safely assumed to be "syntacticized". Whether or not they may be taken to shed light on foundational questions pertaining to the organization of semantics, it would be interesting to try to find out whether such properties play a distinguished role in human reasoning. One might try to use them to build a calculus that is sound although perhaps highly incomplete and see how far it takes us. Or, one might try to find out whether people are better at making inferences that hinge on such properties than inferences that hinge on syntactically indistinguished ones.[28]

Bernardi and Szabolcsi 2005 asked a more modest question, pertaining to whether and how the word-order based inclusion relations between categories can be combined with ones inspired by semantic inclusion relations; so to speak, how much semantic insight can be stuffed into this kind of syntax. It turns out that the semantically based inclusion relations among classes of operators cannot be simply imported into the syntax. However, an important kind of insight can be preserved.

The particular inclusion relations studied are ones pertaining to the "negative strength" of functions, as characterized with reference to the de Morgan laws in Zwarts 1993: anti-morphic $\subseteq$ anti-additive $\subseteq$ decreasing functions.[29] These classes have grammatical relevance. All three play a role in some polarity licensing phenomenon (van der Wouden 1997); decreasing adjuncts undergo negative inversion in English; anti-additive but not decreasing direct objects undergo preposing in Norwegian (Kayne 1998; Nilsen, p.c.); and so on. For differences in negative polarity licensing, consider:

(14) a. I couldn't but laugh.
b.* I could never but laugh.
c.* I could seldom but laugh.

(15) a. I didn't sleep a wink.
b. I never slept a wink.
c.* I seldom slept a wink.

(16) a. I haven't seen anything suspicious.
b. I've never seen anything suspicious.
c. I've seldom seen anything suspicious.

Thus syntax has to reckon with these properties, or some reflexes thereof. Furthermore, the inclusion relations themselves are relevant. For example, weak negative polarity items like *ever* or *any* are licensed by operators that are decreasing or stronger, and negative inversion affects adjuncts that are decreasing or stronger. Call this the monotonicity of the licensing relation. One hopes to capture it in the form of an entailment, rather than having to tag *never*, for example, separately for being anti-additive and for being decreasing.

Assuming the usual category/type correspondence, the semantic inclusion relation between classes of functions can be translated into syntactic inclusion / derivability relations between their argument categories and value categories. If $F_3 \subseteq F_4$, then $val_3 \leq val_4$ and

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[28] I have been conducting preliminary studies with Lewis Bott at NYU.

[29] f is anti-morphic (AM) iff $f(a \vee b) = fa \wedge fb$ and $f(a \wedge b) = fa \vee fb$ e.g., *not*
f is anti-additive (AA) iff $f(a \vee b) = fa \wedge fb$ e.g., *never*
f is decreasing (DE) iff $f(a \vee b) \rightarrow fa \wedge fb$ e.g., *seldom*

$arg_4 \leq arg_3$.[30] The observation that OP_a can scope over OP_b iff $val_b \leq arg_a$ allows us to connect the two issues and to explore the empirical predictions made by incorporating $F_3 \subseteq F_4$ into the partial order of syntactic categories. A prediction that holds irrespective of the specific logic we use to define the partial order is as follows.

(17) If the class of operators that OP_3 belongs to is included in the class that OP_4 belongs to, and the corresponding derivability relations between value and argument types are part of the syntax then, if either OP_3 or OP_4 can directly outscope the other, OP_3 is predicted to directly outscope itself, i.e. to be iterable.

If $val_3 \leq val_4$ (by inclusion) and $val_4 \leq arg_3$ (by scope), then $val_3 \leq arg_3$.

If $val_3 \leq arg_4$ (by scope) and $arg_4 \leq arg_3$ (by inclusion), then $val_3 \leq arg_3$.

This prediction is not borne out by the facts. For example, anti-morphic sentential negation is at the bottom of the semantic inclusion hierarchy and in Hungarian as well as many other languages it can be outscoped at least by merely decreasing operators -- but it is not iterable. (Apparent examples of iterability involve the intervention of focus.) This result indicates that the semantically based inclusion relations among classes of operators cannot be simply imported into the syntax.

Fortunately, this does not mean that the monotonicity of licensing cannot be incorporated. To capture that, it suffices if the derivability relations indicated in (18) obtain. In (18) the cover term "licensee" stands for any structure that needs to be directly outscoped by a particular kind of operator (the "licensor"). For example, a licensee can be a structure containing a negative polarity item (*have seen anything suspicious*) or one involving inversion (*would a whale fly*), with *never* serving as a "licensor" in either case. What we see is that the argument and value categories of the licensors themselves can be unordered with respect to each other (derivationally independent), and thus the iterability prediction is no longer made. In (18) derivability arrows instead of ≤ are used for the sake of readability.

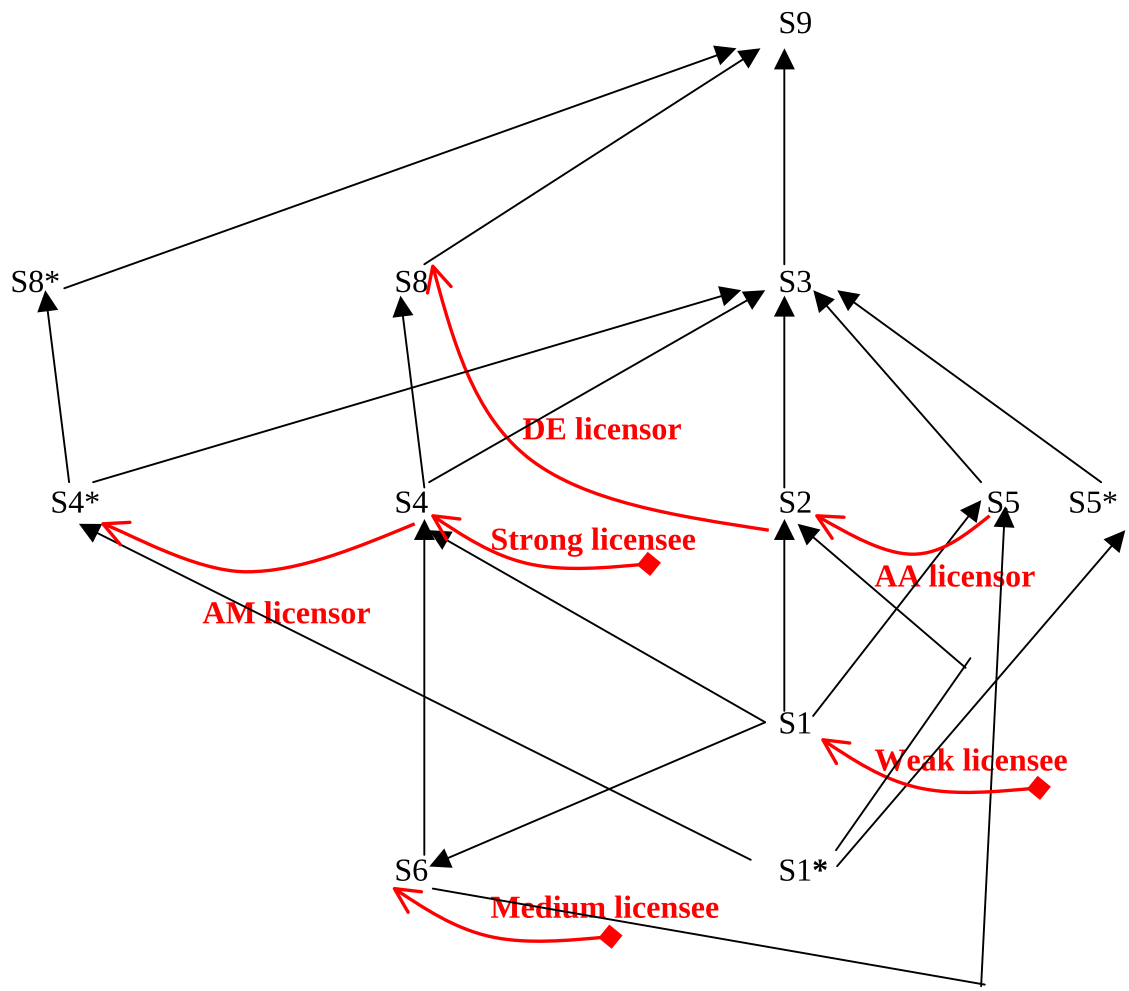
(18)
$$
\begin{array}{lcl}
\text{val. of weak licensee} & \rightarrow & \text{arg. of weak (DE) licensor} \\
\downarrow & & \\
\text{val. of medium licensee} & \rightarrow & \text{arg. of medium (AA) licensor} \\
\downarrow & & \\
\text{val. of strong licensee} & \rightarrow & \text{arg. of strong (AM) licensor}
\end{array}
$$

The requirement in (18) may be possible to satisfy. Details aside, imagine that a language that has operators as in (13) also has (i) an anti-additive quantifier which, like English *no one*, does not directly scope above local negation but can be outscoped by decreasing operators,

[30] For any function, if the set X is in the domain of f, then Y≤X is also in the domain of f. In other words, the domain, unlike the range, is anti-tone (downward monotonic).

i.e. is of category <S5,S2> and (ii) a weak licensee with value category S1, a medium licensee with value category S6, and a strong licensee with value category S4.

(19)



This conforms to the desired pattern as follows:

(20)	val. of weak licensee : S1	→	arg. of weak (DE) licensor : S2
	↓		
	val. of medium licensee : S6	→	arg. of medium (AA) licensor : S5
	↓		
	val. of strong licensee : S4	→	arg. of strong (AM) licensor : S4

It may sound disappointing that the actual semantic inclusion relations cannot be included in the syntax, but there is reason to believe that (at least in this case) this is empirically correct. Negative polarity licensing is monotonic in English and many other languages, but not in Serbo-Croatian or Hungarian, for example. Progovac 1994 observed that the distribution of *anything* is covered by two complementary items in Serbo-Croatian: *ništa* in the context of clause-mate negation and *išta* elsewhere. Thus the licensing of *išta* is non-monotonic: while it is licensed by clause-mate DE operators, it is not licensed by (all) clause-mate AM ones. The same holds for Hungarian. If derivability relations corresponding to semantic inclusion were part of the syntax, polarity licensing would be predicted to be invariably monotonic, excluding Serbo-Croatian and Hungarian.

The observations of this case study show that syntactic and semantic inclusion cannot be collapsed. On the other hand, they do not in any way suggest that the features under consideration cannot serve both syntax and inferencing.

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