Is the language faculty non-linguistic: a view from generative syntax

David Adger and Peter Svenonius
Queen Mary University of London and the Arctic University of Norway

April 2015

1 Introduction

We take the core question behind this special issue to be whether explaining linguistic phenomena requires appeal to properties of human cognition that are specialised to language. It seems to us that the only reasonable way to answer this question, given the current state of knowledge in cognitive science, is simply to develop theoretical approaches to linguistic phenomena which have as much empirical reach and explanatory depth as possible, and to ask whether such theories require posits that are best interpreted as proprietary to language. There is nothing particularly totemic in the issue, at least from the perspective of generative syntax. We should hope that various principles of our best theories of syntactic phenomena are simply special cases of more general principles. But those more general principles are not established at the moment, at least not in such a way as provide deep explanations of even rather elementary properties of human syntax. Indeed, we think that generative syntax provides a potential way to reach those more general principles, and that human language is a particularly rich domain for the development of theories of some depth that may allow us to glimpse any deeper underlying regularities.

We will make the general argument here through one single case, the phenomenon of bound variable anaphora. The argument goes as follows: (i) the phenomenon is a real phenomenon of human language in general; (ii) there is a compelling generative theory that limns its empirical contours rather exactly; (iii) there are no equally empirically wide or theoretically compelling competing accounts; (iv) some aspects of the successful theory, currently at least, involve concepts that do not reduce to domain general principles of knowledge acquisition or representation. It follows that there are aspects of syntax, as currently best understood, that we do not know how to reduce to more general principles.

There are two ways to proceed (aside from rejecting the theoretical characterization entirely, which simply begs the question of what the account of the data is): (i) attempt to reduce the relevant concepts in the theory to domain general principles of cognition that we have good theoretical accounts of; (ii) take the principles of the syntactc theory to provide clues to new principles of cognition, perhaps operative in domains outside of language. Both avenues of exploration are, we contend, viable and exciting. We will provide some discussion of option (ii) in the conclusion to the paper.

Often generative syntactic analyses can be impenetrable to those trained outside of the discipline, so we attempt here to drill down to the core essentials and to make these accessible, drawing out the more general theoretical implications for cognition, and examining to what extent the theoretical principles we use are specific to linguistic cognition.

2 Structural Constraints on Interpretation

2.1 Introducing Bound Variable Interpretations

The phenomenon we will use to make the argument here is known as bound variable anaphora. Take the English sentence in (1):

(1) No woman denies that she has written a best selling novel.

What is the meaning of this sentence? There are two that are readily discernible (Evans, 1980). One is that, from a group of women, not one denied that some individual (say Julie) had written a best selling novel. This meaning is easily accessible given either a preceding discourse to provide context, or, an individual that is salient in the context where the sentence is uttered. For example:

(2) Hello everyone. This is Julie, who's recently been in the news again. Now, no

woman denies that she has written a best selling series of novels featuring female protagonists, but some deny that these novels are good for equal rights.

Following Evans, we'll call this meaning, where the pronoun receives its interpretation from the context, the *referential* meaning.

The second meaning is simply that, if you have a group of women, and you check all of them one by one, you will not find any who deny that they themselves have written a best selling novel. This is called the *bound variable* meaning.

We also find this ambiguity effect with quantifier phrases containing quantifiers other than *no*. For example, all of the following sentences have the same ambiguity; the pronoun can have a referential or a bound variable interpretation:

(3) a. Every woman said she had met the Shah.
b. Did any woman say that she had met the Shah?
c. Every woman persuaded her son to organize her birthday party.
d. Each author decided that she should be at the signing.

We find bound variable anaphora in various languages. For example, the Athabaskan language Passamaquoddy displays the same effect (Bruening, 2001):

(4) Psi=te wen litahasu eli w-itapi woli-pomawsuwin-uw-ulti-htit
all=Emph someone think.3 that 3-friend.ObvP good-person-be-Plural-3PConj
'Everyone thinks his friends are good people.'

(5) Ma=te wen litahasi-w nekom mahtoqehs.
Neg=Emph someone think.3-Neg he rabbit
'No one thinks he's a rabbit.'

(6) Ma=te wen ?-kosiciy-a-wiy-il eli Maliw-ol muhsal-iht.
Neg=Emph someone 3-know.TA-Dir-Neg-Obv that Mary.-Obv like-3ConjInv
'No one knows that Mary likes him.'

The following examples from Scottish Gaelic also show the same effect:

(7) Thuirt gach caileag gu robh i a' faireachdainn tinn.
Say.PAST each girl that be.PAST she PROG feeling sick
'Every girl said she was feeling sick.'

(8) Cha robh caileag sam bith ag ràdh gu robh i tinn.
NEG be.PAST girl in being PROG say that be.PAST she sick.
'No girl said she was sick.'

We have given these non-English examples to show that this phenomenon is not simply a grammatical quirk of English or other well studied European languages. The exact empirical countours of bound variable anaphora, as outlined here and explained below, are not, however, detectable in every language. For a language to display this particular pattern, it needs to have determiner quantifiers, which not all languages possess (Bach et al., 1995). Further, it must have a determiner quantifier that is singular. English has both singular determiner quantifiers (as in 'every boy') and plural ones (e.g. 'all boys'). Some languages, however, lack singular determiner quantifiers. Further, the language must ideally be able to use singular pronouns with the singular quantifier to create the relevant reading. This is also not available to all languages. Indeed, in English, the plural pronoun is often used in informal discourse, especially when the gender of the quantified noun phrase is unknown or avoided: for example 'Every author was able to choose their own cover'. In such circumstances, the plural pronoun can be construed as refering to a group of individuals that is constructed out of all the authors, similarly to the behaviour of *they* in following discourse in English: 'Every author was grumpy. They had been locked out of the decision about their book covers' (Kamp and Reyle, 1993; Rullmann, 2003). The existence of this strategy makes discerning true bound variable readings with plural pronouns challenging. Beyond these basic requirements, languages place various other restrictions on their pronouns which mean that quite far reaching investigation is required to determine whether there is a bound variable construction. However, we can control for these relevant factors by cross-linguistic investigation, and when the various conditions listed are met, the phenomenon reveals itself to be very consistent.

Bound variable interpretations of pronouns, then, arise when the meaning of a singular pronoun is dependent in a particular way on the meaning of a singular quantifier phrase elsewhere in the sentence (the importance of number and person features for bound variable meanings across languages is discussed in Kratzer (2009), Adger (2010); see Harbour (2014) for a compatible theory of grammatical number). When a bound variable interpretation is available in the examples we have seen, a referential interpretation is also available, leading to the ambiguity.

Let us turn now to structural constraints on the availability of this interpretation. In certain cases, it turns out that the bound variable meaning vanishes, and only the referential reading is left. For example:

(9) a. A man who no woman likes denies that she has written a best selling novel.
 b. The man that every woman loved said she had met the Shah.
 c. The man that didn’t love any woman said she had met the Shah.
 d. That every woman seemed so sad persuaded me to organise her birthday party
 e. Because every author hates you, she will try to kill you.

If one pauses to think about the meanings of these sentences, it turns out that they are not interpreted as involving the pronoun’s meaning varying with the quantifier in the way we have just seen. Compare, for example, (9-b) with (3-a). (3-a) can be paraphrased as “Take a set of women. Now, for each choice of some woman you make from that set, ensure that it the case that that woman you have chosen said that she herself had met the Shah”. A corresponding paraphrase for (9-b), would be “Take a set of women. Now, for each choice you make from that set, the man that didn’t love the woman you have chosen said that that that woman had met the Shah.” But that paraphrase doesn’t capture the meaning of the sentence in (9-b). In fact, the sentence only has a paraphrase that goes something like “Take a set of women. Now the man that didn’t love any woman you may chose from that set said that that some other female person had met the Shah.” That is, the pronoun *she* is not ambiguous between the two interpretations: it is only referential. This is an odd meaning out of context, but is the only meaning available.

This same effect holds for the other sentences, and countless more pairs like them. Although we have illustrated the phenomenon just by appealing to what meanings are intuitively available for sentences here, it is experimentally robust (Kush et al., 2015).

The same effect holds in Passamaquoddy and in Scottish Gaelic, where, in certain circumstances, the bound variable interpretation is unavailable. (The * in the examples here marks not ungrammaticality, but rather the unavailability of the bound variable reading).

(10)	*Ipocol	psi=te	wen	Sipayik	k-nacitaham-oq,	kt-oqeci=hc	nehpuh-uk
	because	all=Emph	someone	Sipayik	2-hate-Inv	2-try=Fut	kill-Inv

'Because everyone at Sipayik hates you, he will try to kill you.'

And in Gaelic

(11) a. *Thuirt duine a bhruidhinn ris gach caileag gun robh i tinn
say.PAST man that spoke to each girl that be.PAST she sick
'A man that was talking to each girl said she was sick.'

b. *Air sgath 's gu bhuail thu gach balach, ruith e air falbh
because that hit.PAST you each boy, run.PAST he away
'Because you hit each boy, he ran away.'

In examples like those in (9), (10) and (11), the quantifier precedes the pronoun just as it does in the examples in (1) and (3). However, the bound variable reading is available in (1) and (3) and is unavailable in (9), (10) and (11). So the issue is not (merely) one of precedence. Various proposals have been put forward in the generative literature as to what, exactly, is responsible for the difference. The current consensus is that there are two interrelated factors involved: semantic scope and syntactic command (Safir 2004, Barker 2012).

2.2 Scope

Scope is simply a name for the fact that the interpretation of certain units of language is computed as a subpart of the interpretation of larger units, a cognitive factor that plausibly exists elsewhere than in language. The larger unit is said to take wide scope over the smaller unit. Consider the following cases:

(12) a. An author read every book
b. An author thought every book was good.
c. An author thought Julie had read every book.

In (12-a), there are two meanings. In one meaning, we interpret the phrase *an author* as dependent on the interpretation we provide for *every book*; that is, the semantic computation that builds the meaning of *every book* includes a meaning assigned to *an author*. In the other, the dependency is the other way around. We can make this intuition explicit by sketching a procedure to compute the meaning of the quantifier phrases. Let us take a simpler example first:

(13) Every book is interesting.

We can treat computing the meaning of *every book* as involving three separate computational procedures (Peters and Westerståhl, 2006):

(14) a. Assume a salient set in the context of the discourse; in this case a set of books

b. Quantify in some fashion over the elements of that set; in this case, ensuring that every element of the set is such that the final part of the computation in (c) holds of it.

c. Determine whether the condition represented by the remainder of the sentence holds of whatever elements of the set are picked out by the quantifier; in this case the condition is that the elements picked out of the set by the quantifier are interesting.

Similarly, we compute the meaning of *an author* by taking a set of authors and checking whether a condition represented by the rest of the sentence holds of one of the elements of that set.

(15) An author won this week's lottery.

(16) a. Assume a salient set in the context of the discourse; in this case a set of authors

b. Quantify in some fashion over the elements of that set; in this case, ensuring that at least one element of the set is such that the final part of the computation in (c) holds of it.

c. Determine whether the condition represented by the remainder of the sentence holds of whatever elements of the set are picked out by the quantifier; in this case the condition is that the elements picked out of the set by the quantifier won this week's lottery.

These trivial cases are then put together for our example (12-a). We can take either the set of books first, and then compute the condition that holds of every book as involving an author, or we can take an author first, and then see whether the condition involving every book holds of an author. This gives us two distinct meanings.

Let's take *every book* first:

(17) Take a set of books salient in the context. Now go through the books one by one, and for each choice you make of a book, see whether an author (from a salient set of authors) has read that book. Going through the set of books, ensure that for all of the choices of book some author has read the book chosen.

This process implies that it is possible to have a different author for each book. This is the *wide scope* reading for *every*, as the computation of *an author* takes place within the computation for *every book*. The other meaning of *an author read every book* works out as follows:

(18) Take a set of authors salient in the context. Now go through the authors one by one and for each choice made, go through the set of books salient in the context and see whether the author you have chosen has read every member of the set of books. Ensure that there is at least one author of whom this condition holds.

This is the *narrow scope* reading for *every*. The crucial empirical difference is that in the wide scope reading for *every book*, we can have a different author picked for each different book, while in the narrow scope reading, once we've picked our author, that author needs to like every book.

It turns out that there are structural constraints on the scope of quantifiers. Consider the sentence in (12-b): this doesn't have the wide scope reading for *every*. Neither does the sentence in (12-c). This is because a quantifier cannot scope outside the tensed clause it is in. This idea, that certain semantic effects are bound into local syntactic domains, is of venerable descent in linguistics, originally due to Langacker (1969). We'll call it the Command Generalization:

(19) The Command Generalization: A quantifier scopes over everything in the mini-

mal finite clause it appears in.

2.3 Applying Scope to Bound Variables

The generalization that seems to be most effective in determining when a quantifier phrase can bind a pronoun is the following (this is just a descriptive generalization, not a theory, as yet):

(20) The Scope Generalization: For a quantifier to bind a pronoun it must scope over that pronoun.

For example, consider the following example:

(21) Every woman says that she has written a best selling novel.

This sentence has the following rough paraphrase: take a set of women. Now go through that set one by one, and see whether, for each choice of a woman, that woman said that she, herself, wrote a best selling novel. For the sentence to come out true, all of the choices of individuals from the set of women should work.

Now compare that to the following case:

(22) A man who every woman likes says that she has written a best selling novel.

If the quantifier phrase *every woman* could scope over the rest of the sentence, it should be able to bind the pronoun. But we can independently tell that *every woman* is restricted in its scope. If we put a quantifier phrase like *an author* in place of *she*, we get:

(23) A man who every woman likes says that an author has written a best selling novel.

We can see that *every woman* doesn't, descriptively, scope over *an author*, because the sentence doesn't have a reading where the authors potentially change for each choice made from the set of women. So the Scope Generalization correctly correlates the capacity of a quantifier to scope over the pronoun with its ability to bind the pronoun. The Command Generalization captures why the quantifier doesn't have wide scope over the pronoun in this sentence: the quantifier is 'trapped' within the finite (relative) clause *who every woman likes*.

There is also other evidence that a quantifier's ability to bind a pronoun tracks its ability to scope over the pronoun.

Some languages explicitly mark the scope of quantifier phrases with a special particle. In Chinese, for example, the particle *dou* appears in the clause where an associated quantifier scopes. In the following example, *dou* appears inside a relative clause, together with its associated quantifier phrase *meige ren*, 'every man'. Since *dou* marks the scope of that quantifier phrase as falling inside the relative clause, the following Chinese example works just like English. The quantifier cannot scope outside of the relative clause, and a bound variable interpretation of the pronoun *ta* is impossible (Huang 1982).

(24) meige ren dou shoudao de xin shangmian you ta taitai de mingzi
every man DOU receive DE letter top have he wife DE name
'The top of the letter that every man received has his wife's name (on it)'

However, Chinese behaves differently from English with respect to the Command Generalization. *Dou* marks the scope of its associated quantifier phrase, even when *dou* appears in the main sentence, rather than in the relative clause. One might take the Command Generalization to vary across languages, so that a quantifier can take scope outside finite clauses in Chinese but not in English (possibly because finiteness is distinct in the two languages). An alternative is to say that the quantifier in Chinese is really *dou*, and that the apparent quantifier phrase just functions as a modifier of *dou* (Shimoyama, 2006). In any event, when *dou* appears in the main sentence, it marks the scope of the quantifier phrase embedded inside the relative clause as being the whole sentence rather than just that relative clause. In this case, the pronoun *ta* can now receive a bound variable meaning:

(25) meige ren shoudao de xin shangmian dou you ta taitai de mingzi
every man receive DE letter top DOU have he wife DE name
'For each person, the tops of the letters he received have his wife's name on them'

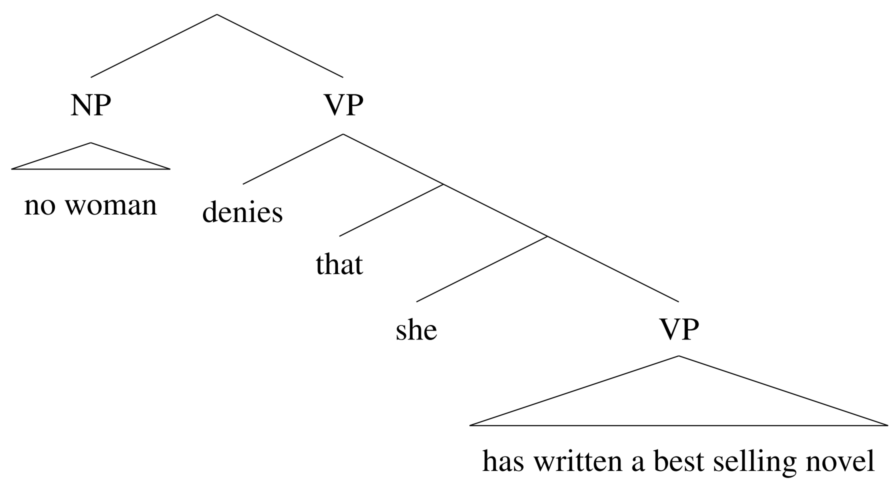
The Chinese facts strongly support the Scope Condition, as the pronoun in (24) and (25) can only receive a bound variable interpretation when the quantifier scopes over it, as marked by the grammatical position of *dou*.

Together, the Scope Generalization and the Command Generalization do a good job of capturing the data we have seen. Consider again, our first example:

(26) No woman denies that she has written a best selling novel.

Here, the smallest finite clause containing the quantifier phrase *no woman* is the whole sentence. That sentence contains a further clause *that she has written a best selling novel* and that clause contains the pronoun. So *no woman* scopes over the pronoun *she* and she can therefore have a bound reading, in the way described above. For visualisation's sake, we can represent this as a tree-like structure, where the scope of a quantifier phrase is its sister in the tree:

(27)

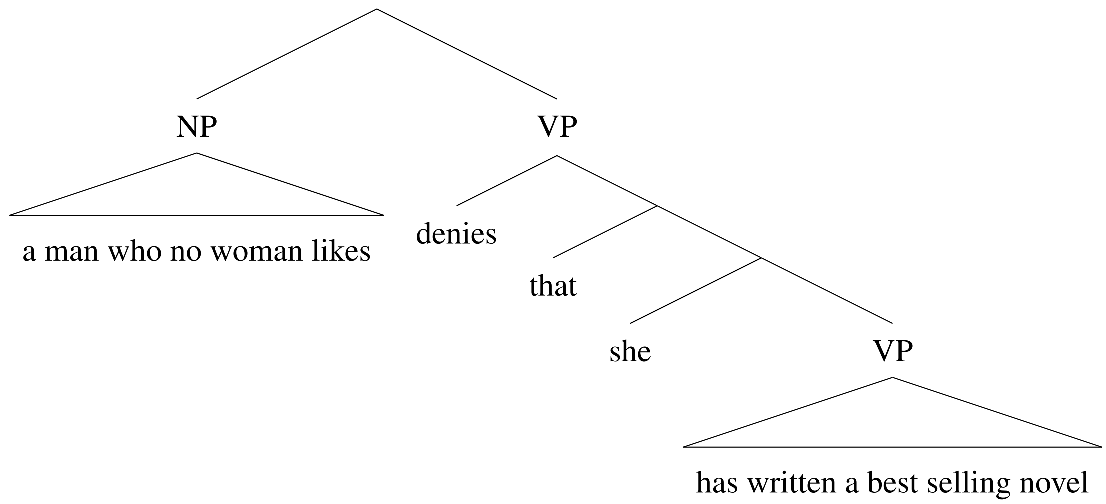


Compare this with the corresponding example from (9), which lacks a bound variable interpretation:

(28) A man who no woman likes denies that she has written a best selling novel.

No woman is in a finite (relative) clause of its own *who no woman likes*. It cannot therefore take scope over the whole sentence, so the pronoun *she* cannot be bound. Again, we can visualise the structure in a tree-like fashion:

(29)



Here the scope of the quantifier phrase is again its sister in the tree, but the sister of *no woman* is just the verb *likes*, and so the quantifier phrase does not scope over the pronoun.

Our descriptive generalizations also capture the fact that the bound reading vanishes in examples like the following:

(30) a. She persuaded the Shah that every woman should be imprisoned.
b. She didn't believe that I had been introduced to any woman.
c. She expected that each author's book signing would be private.

Here, the quantifier phrases are inside an embedded finite clause, and the Command Generalization stops them scoping over the whole sentence, so the pronoun cannot be bound. (30-a), for example, can't have a paraphrase where for each individual chosen from a set of women, that individual persuaded the Shah to imprison her.[1]

[1]There is one final aspect to the phenomenon of bound variable interpretations which is not captured by scope and command: sometimes a quantifier phrase can take scope over a pronoun, but it cannot bind it. This happens when the pronoun appears as a subject and the quantifier phrase as an object. Recall that in (12-a), *every book* can take scope over the subject *an author*. If all that is required is the Scope Generalization, examples like the following should be well formed with a bound variable reading:

(i) a. She loved every author.
b. He killed each man.

(ii) a. Her publicist loves every author.
b. His friend killed each man.

Summarizing, we have seen that the phenomenon of bound variable anaphora is a real phenomenon, appearing cross-linguistically in unrelated languages when the conditions allow it to be detected. We have also seen that its empirical distribution can be described by a number of high-level descriptive generalizations:

(31) The Scope Generalization: For a quantifier to bind a pronoun it must scope over that pronoun.

(32) The Command Generalization: A quantifier scopes over everything in the minimal finite clause it appears in.

These generalizations appear to involve concepts that are quite specific to language: quantifier, binding, pronoun, scope, minimal finite clause. Is it possible to derive these generalisations from more abstract principles which rely less on apparently language specific concepts? We take up this challenge in the next section.

3 A Theoretical Account

Generative accounts of linguistic phenomena are couched at a level of analysis that is close to Marr's 1982 Computational Level. That is, the theory specifies a system that guarantees a particular pairing of sounds and meanings across a potentially unbounded domain. A helpful analogy would be an axiomatised theory for arithmetic, that can specify, for a potentially infinite set of pairs of integers, what the sum is. How people actually add, that is, how they use this system, is distinct from what the system is. The kinds of

---

The examples in (i) cannot mean: assume a set of authors, and choose each member of the set, ensuring that there is a set of female people where you can choose a different female person for each author (mutatis mutandis for the cases in (ii)). Rather the female person chosen for the pronoun to refer to must be not in the set of authors at all. This doesn't follow from what we have said so far.

These phenomena (noted for questions by Postal (1971), extended to quantifiers by Chomsky (1976), and dubbed Strong and Weak Crossover respectively) cannot be captured by the Scope and Command Generalizations alone. Various approaches have been taken to this phenomenon, and there is no clear consensus. For our purposes here, in an argument about whether bound variable interpretations require a specifically linguistic theory, we'll simply note the phenomenon for completeness sake, but will not attempt to provide a theory of it.

empirical effect described above, when structures are ambiguous or not between referential and bound variable interpretations of pronouns, is specified by the system at the computational level. How that system is put into use in parsing, production, etc., is a distinct question (Chomsky 1967 et seq).

Within current generative grammar, one approach that has been taken to the core question of how to pair up particular linguistic forms of sentences with their meanings is the theory of Merge. Merge is a principle of structure generation that is incorporated into a theory of what legitimate syntactic structures can be. It says that a syntactic unit can be combined with another syntactic unit to make a new syntactic unit, capturing the potentially unbounded nature of language.

We can recursively define a syntactic unit as follows (cf. Chomsky 1995):

(33) a. Lexical items are syntactic units
b. If A and B are syntactic units then Merge(A, B) = {A, B} is a syntactic unit.

This theory takes us from a finite list (of word-like atomic lexical items) to an unbounded set of hierarchical structures. (33) is a theory of what the legitimate structures in human language are, presumably neurally implemented (Embick and Poeppel 2015). But these structures are useless unless they interface with the systems of sound and meaning. The definition of syntactic unit, incorporating Merge, in (33) is not sufficient for specifying language unless we add a set of principles for mapping those objects to interpretations in terms of sound and meaning. This is a point that often goes under-appreciated in literature, following Hauser et al. (2002), about whether language just consists of recursion.

One such mapping principle has to do with the timing of when the syntactic objects built are transferred to the phonological and semantic systems: the idea is that syntax has a periodicity, so that mapping takes place at certain points in the construction of a syntactic object (again, keeping to the computational level here). We will take these points to be finite clauses; though that is a simplification (Chomsky 2008), it should be sufficient for our purposes here. This is our first interface mapping principle:

(34) Transfer of Finite Clauses: Transfer the minimal structure containing the finite complementiser (*that* in English) to phonological and semantic computations.

> Once a structure has been transfered, it is no longer accessible to further syntactic computation.

The phonological and semantic computations transduce information delivered by the structure building system into forms that can be used by mechanisms of processing, production, planning, etc.

These two very general theoretical principles, Merge and Transfer, are motivated by empirical phenomena unconnected to bound variable anaphora. Merge is motivated by the need to capture basic constituency and hierarchy effects in human language, while Transfer of Finite Clauses is motivated by the special status finite clauses have in syntactic phenomena in general: they are the locus of subject case assignment, of semantic tense specification, and of locality domains for displacement operations (Adger 2015 for review). However, these two ideas, as we will show, take us a long way in capturing the empirical distribution of the bound variable interpretation phenomenon, which we now turn to.

We notate syntactic units as sets. When a syntactic unit is transferred, the result is notated as a set, flanked by a phonological representation above and a semantic one below.

We simplify phonological representations massively by using orthographic representations and a simple concatenation operator $\frown$ to represent string order. There is far more structure in phonological representations, including information about prosody, phonological phrasing, and segmental properties, but we will ignore this here.

We simplify semantic representations by using a simplified logical representation with variables and connectives augmented by a representation for natural language quantifiers. Following much work in semantics, as well as the discussion above, we take a quantified sentence to have three semantically contentful parts: a domain restriction, the quantifier itself, and a scope (Barwise and Cooper 1981). These correspond to the computational operations described above: identifying a salient set in the context, quantifying over it, and determining whether a condition holds of the members of the set picked out by the quantifier. We notate these three parts, as is standard, by writing the quantifier plus the variable it binds, a colon, then the restrictor in square brackets followed by the scope in square brackets, thus:

(35) Q x:[...x...][...x...]

This set of simplifying assumptions about the interface mappings will suffice for our purposes here.

Now consider the derivation of the sentence in (36). This derivation should be understood as a computational specification of a sound-meaning pairing, much as a proof in logic is a computational specification of a theorem derivable from a set of axioms. This computational specification is part of a particular linguistic action (say an utterance of (36)), but does not causally determine the action.

(36) Noone said that he danced

(37) a. Merge(he, danced) = {he, danced}

b. Merge (that, {he, danced}) = Transfer, since *that* is a finite complementiser

$$\text{that}\frown\text{he}\frown\text{danced} \leftarrow \text{PHON}$$

{that, {he, danced}}

SEM$\rightarrow$ y danced

Here the hierarchy partly determines order and the pronoun is semantically translated as the variable y.

c. Merge(said, {that, {he, danced}}) = {said, {that, {he, danced}}}

d. Merge(Noone, {said, {that, {he, danced}}}) =

$$\text{noone}\frown\text{said}\frown\text{that}\frown\text{he}\frown\text{danced} \leftarrow \text{PHON}$$

{noone, {said, {that, {he, danced}}}}

SEM $\rightarrow$ No x:[x is a person][x said y danced and x=y]

As the phonological and semantic information is transfered to the relevant interfaces, information about linear order, pronunciation, and semantic interpretation accretes. Crucially, the statement that the variable x has the same value as y is added within the scope of the interpretation of the quantifier *noone*, just as in the informal paraphrase given in the last section. This ensures that it is interpreted as bound. Of course, we can equate x to another variable not in the scope of the quantifier, in which case we get the referential reading, thus accounting for the core ambiguity we began with. This equation of variables is a purely semantic, possibly non-linguistic process, at the heart of anaphoric dependency of all sorts, but the bound interpretation is constrained by the timing of when the syntactic structures are interpreted, as we shall see directly.

Now let us look at a case where variable binding is not possible:

(38) Friends that no woman knew said that she danced.

In the following derivation steps (a-c) build up the verb phrase *said that she danced* and steps (d-h) independently build up the subject *Friends that no woman knew*. Although (d-h) is ordered after (a-b), this is just an artefact of writing down the derivation. One can think of these as separate derivations taking place in parallel.

(39) **a.** Merge(she, danced) = {she, danced}

b. Merge (that, {she, danced}) =

$$\text{that}\frown\text{she}\frown\text{danced} \leftarrow \text{PHON}$$
$$\{\text{that}, \{\text{she}, \text{danced}\}\}$$
$$\text{SEM}\rightarrow \text{y danced}$$

Steps (a-b) build up the embedded clause *that she danced*, which contains the pronoun of interest.

c. Merge(said, {that, {she, danced}}) = {said, {that, {she, danced}}}

d. Merge(knew, friends) = {knew, friends}

e. Merge(no, woman) = {no, woman}

f. Merge({no, woman}, {knew, friends}) = { {no, woman}, {knew, friends}}

This part of the derivation builds up the relative clause *that no woman knew*. Note that the item *friends* is Merged with the verb *knew*, which is why it is interpreted as the object of that verb. However, the actual relative clause has a gap in the object position. This necessitates the next part of the derivation:

g. Merge(that,{ {no, woman}, {knew, friends}}) = {that,{ {no, woman}, {knew, friends}}}

h. Merge(friends, {that,{ {no, woman}, {knew, friends}}}) =

The subject *friends that no woman knew* involves a further Merge operation that takes the object of the verb *knew*, which is the unit *friends*, and Merges it with the whole structure *that no woman knew friends*. This happens in English because of a property of relative complementisers that triggers this displacement. Languages vary in whether relative clauses involve this kind of displacement Merge, with some leaving the object in its base position (Cole 1987).

At this point, the whole relative clause is built up. Following the Transfer principle, what is transfered is the unit containing the relative complementiser *that*:

$$\text{that}\frown\text{no}\frown\text{woman}\frown\text{knew} \leftarrow \text{PHON}$$
$$\{\ \text{friends}, \{\text{that},\{\ \{\text{no, woman}\}, \{\text{knew, friends}\}\}\}\}$$
$$\text{SEM} \rightarrow \lambda\text{y: No x:[x is a woman] [x knows y]}$$

In English, as just mentioned, only the higher of the two occurrences of *friends* is pronounced. In other languages, the lower occurrence is pronounced. We do not know of languages where both occurrences are pronounced. This suggests another mapping principle:

Pronounce One Occurrence:When a single object appears at more than one position in a structure, pronounce only one instance.

This principle, together with the Transfer principle, gives us the phonological representation above.

The semantics associated with this piece of structure is the tripartite structure we are familiar with, whose domain is restricted to a set of women, and whose scope is the verb phrase of the relative clause (basically the verb *knew* and its object). We adopt a standard approach to relative clause semantics (Heim and Kratzer 1998): the transfered object *friends* is just translated to a variable bound by the relative complementizer *that*, and we notate this semantics in the standard way as λy:[...y...].

i. Merge({ friends, {that,{ {no, woman}, {knew, friends}}}}, {said, {that, {she, danced}}})

$$\text{friends}\frown\text{that}\frown\text{no}\frown\text{woman}\frown\text{knew}\frown\text{said}\frown\text{that}\frown\text{she}\frown\text{danced} \leftarrow \text{PHON}$$

{ { friends, {that,{ {no, woman}, {knew, friends}}}}, {said, {that, {she, danced}}}}

SEM → some y: [y are friends and No x: [x is a woman] [x knows y]] [y said w danced]

> The final chunk of the derivation combines the whole subject with its VP. The VP is built up in step (c), and the output of that is Merged with the output of step (h). Phonologically, we simply concatenate these in the order required by English. Semantically, we take the bare noun *friends* to be interpreted as an existential quantifier *some*. We identify the variable this quantifier binds with that of the relative clause, and that is the variable that is the subject of the verb phrase. The pronoun in the embedded clause is translated as a further variable.

At this point, however, it is not possible to connect x and w, since the interpretation of the quantifier phrase *no woman* has already been completed, and the variable x has been fully interpreted, before w is encountered. This derives the simple cases of the Scope Generalization directly from very general principles of the relationship between syntax and semantics: the pronoun cannot be interpreted as bound unless it is computed within the scope of the quantifier.

The more outre effects of the Scope Principle are also amenable to the same set of basic principles. Recall that a quantifier can scope over everything inside the finite clause it is immediately contained within. With this in mind, consider the derivation of (40):

(40) She believed that every author danced.

(41) a. Merge(every, author) = {every, author}

b. Merge({every, author}, danced) = {{every, author}, danced}

c. Merge(that, {{every, author}, danced}) = {that, {{every, author}, danced}}

$\text{that}\frown\text{every}\frown\text{author}\frown\text{danced} \leftarrow$PHON

{that, {{every, author}, danced} }

SEM→ Every x:[x is an author][x danced]

d. Merge(believed, {that, {{every, author}, danced}}) = {believed, {that, {{every, author}, danced}}}

e. Merge(she, {believed, {that, {{every, author}, danced}}}) = {she, {believed, {that, {{every, author}, danced}}}}

she⁀believed⁀that⁀every⁀author⁀danced ←PHON

{she, {believed, {that, {{every, author}, danced}}}}

SEM→ y believed that Every x:[x is an author][x danced]

The variable x is fully computed with values assigned, before y is introduced. It follows that the meaning of the pronoun *she* cannot depend on the quantifier, so the bound variable interpretation is correctly predicted to be unavailable.

Compare this to the following case:

(42) Every author's publicist loved her.

(43) a. Merge(every, author) = {every, author}

b. Merge({every, author}, publicist) = {{every, author}, publicist}

c. Merge(loved, her) = {loved, her}

d. Merge({{every, author}, publicist}, {loved, her}) = {{{every, author}, publicist}, {loved, her}}

e. Merge({every, author}, {{{every, author}, publicist}, {loved, her}}) =

every⁀authors⁀publicist⁀loved⁀her←PHON

{{every, author}, {{{every, author}, publicist}, {loved, her}}}

SEM→ Every x:[x is an author][THE y:[y is publicist of x][y loves w and w=x]]

In step (e.), the Merge operation allows the quantifier phrase *every author* to scope, in its finite clause, higher than the pronoun. This computational step is usually called Quantifier Raising, and is a syntactic way of marking the semantic scope of the quantifier, but in the theoretical system it is just another application of the operation Merge.

Just as we saw with the relative clause case, a single syntactic unit (in this case the quantifier phrase *every author*) is Merged with the larger unit that contains it, creating two occurrences of the phrase. One occurrence of this quantifier phrase is now high in the structure. This means that when its semantics is computed, it takes scope over the whole clause. The upshot of this is that the variable introduced by the pronoun is introduced at a point where the variable bound by the quantifier is still being computed. This allows them to be identified (notated here as w=x) and the bound variable reading to arise.

On the phonological side of the computation, one of the occurrences of the quantifier phrase is not transferred to the phonological component following the mapping principle Pronounce One Occurrence (just as we saw with the relative clause). For the case of quantifiers in English (but not, for example in Hungarian, see Kiss (1981)), it is the higher rather than the lower occurrence that is not transferred, giving us the effect that the quantifier is interpreted high in the structure, but pronounced low. No extension of the computational technology already appealed to is necessary to capture this.

We might ask whether we could follow the same kind of derivation we have just seen, and allow the quantifier to Merge higher in (40), hence generating the wrong binding possibilities. However, recall that transfer applies to finite clauses and that once a finite clause is transfered, no further computation is possible. Given this, the quantifier phrase in (40) cannot be moved to a position where it scopes over the pronoun.

The principles sketched here are sufficient to capture the phenomena we have surveyed. The effects of the Scope and Command Generalizations emerge from possible Merge operations interacting with the way that finite clauses are transfered to the phonology and the semantics. We have suceeded in making the descriptive generalizations special cases of much more general principles of structure building and how structures are mapped to the interfaces. We have not shown here how these more general principles play a role in explanations of other phenomena, as this would entail a book rather than a paper. However, these general principles of structure building and mapping to the interface are effective in deriving a slew of generalizations about the syntactic structure of human languages.

3.1 Further Predictions

The theoretical work we have just done, however, goes beyond our core generalizations, because bound variable interpretations interact in a complex way with other phenomena. The following cases do not follow from the generalizations directly, but they do follow from the theoretical system:

(44) a. Which of his relatives did the sybils decree that no man may love?

b. Which of his relatives forced the sybils to decree that no man was innocent?

(45) a. Which of his pictures did you persuade the gallery that every artist liked best?

b. Which of his pictures persuaded the gallery that every artist likes flowers best?

In the (a) examples, the pronoun can receive a bound variable interpretation, which is not available in the (b) examples. Why should this be?

Consider (45-a) in more detail. It includes the phrase *which of his pictures*, which is interpreted as the object of the verb *like* in the embedded clause. This entails that it is initially Merged with *like* in a derivation that then later involves the Merge of *every artist*. The phrase *which of his pictures* is then Merged again with the finite clause, and the remainder of that finite clause is transfered to the phonological and semantic systems, just as we saw for relative clauses above. This means that our derivation will reach a point that looks as follows (we do not show the internal structure of *which of his pictures*):

(46)

that⁀every⁀artist⁀liked⁀best ← PHON

{{[which of his pictures]}, {that, {{every, artist}, {likes, {[which of his pictures]}}}}}

SEM → y: every x:[x is an artist][x likes y: y is a picture of z and z=x]

Here the variable z is introduced for the pronoun *his* at a point in the computation where the phrase *which of his pictures* is in the scope of the quantifier phrase *every artist*. When the finite clause *that every artist likes best* is transfered, the syntactic unit *which of his pictures* is in the object position, and so what is transfered to the semantic computation is a structure where the pronoun's interpretation is computed within the computation of the quantifier phrase. Because of this, we can add the condition that z=x, where x is the variable introduced by the quantifier phrase. The higher occurrence of the phrase *which of his pictures* then undergoes further Merge, after the introduction of the material in the higher clause, to derive the whole sentence with the bound reading.

Compare this, however, to (45-b). Here the phrase *which of his pictures* is the subject of the higher verb *persuade*. It is never, therefore, in the scope of the quantifier phrase *every artist* at any point in the derivation, and there is therefore no means of allowing the pronoun *his* to be bound by that quantifier. The underlying system of computations that build structure and transfer it to phonological and semantic systems correctly predicts a rather sophisticated distribution of form-meaning relations, going well beyond the basic descriptive generalizations.

3.2 Alternatives

We have now come most of the way through the argument. We have introduced the phenomenon of bound variable readings and seen that it is present cross-linguistically; we have outlined the core aspects of the phenomenon and shown how the descriptive generalizations about the phenomenon derive from a theoretical account built on deep, abstract principles stated at a computational level of analysis that specifies the sound-meaning relationships for an unbounded set of structures. We have also shown how that system extends to the interactions between bound variable anaphora and other syntactic and semantic phenomena. In the next section we examine the extent to which the core principles of the system are proprietory to language, but before we do this, it is important to consider whether there are any compelling competitor accounts that can attribute the phenomenon to non-linguistic principles.

The answer to this question is that there are not. The only in depth discussion of the phenomenon that is non-generative and covers a similar range of empirical phenomena is van Hoek (1996), who provides an investigation of bound variable anaphora within the framework of Cognitive Grammar. Van Hoek argues that whether a pronoun can be bound is dependent on the salience or prominence of the quantificational antecedent. For the relevant cases, she defines salient as occupying the Figure in a Figure-Ground structure. Figure Ground relations are plausibly used across cognition (Talmy 1975). The Figure Ground relationship is conceived of purely semantically in van Hoek's work. We give here a standard specification of how this relation is to be understood within language

(Talmy 2000, 312):

(47) a. The Figure is a moving or conceptually movable entity whose path, site, or orientation is conceived as a variable, the particular value of which is the relevant issue

b. The Ground is a reference entity, one that has a stationary settng relative to a reference frame, with respect to which the Figure's path, site, or orientation is characterized

No doubt the notion of Figure-Ground relation is an important semantic schema in cognition. However, contrary to van Hoek's proposal, it does not seem to be implicated in defining salience for bound variable anaphora. There are numerous cases where the subject of a sentence is the Ground, rather than the Figure but this does not impact on the distribution of bound variable anaphora.

Talmy gives examples such as *the room filled with smoke*, where the Figure is the smoke which moves or changes with respect to the room, which is therefore the Ground. In van Hoek's approach, we would expect the object to act as a salient antecedent for a pronoun in the subject position, but this is not what we find:

(48) a. Each room filled with the scent of the flowers in its centre.

b. *Its vase filled with each blooming flower.

Here we find that a quantifier phrase which is semantically the Ground can bind a pronoun in the Figure, and conversely that a quantifier phrase that is the Figure cannot bind a Ground pronoun.

The verb *contain*, by definition, also has a Figure as object and Ground as subject. Again, if the Figure is always salient, van Hoek's system incorrectly predicts the wrong binding possibilities:

(49) a. Each book contains its author's biography as an initial chapter.

b. *Its initial chapter contains a synopsis of each book.

Some action verbs, especially those of consumption, are analysed as involving a Figure object moving with respect to a Ground subject. Once again, the binding patterns we see empirically are unexpected on an approach like van Hoek's.

(50) a. Each giant gobbled up his own child.
b. *His child gobbled up each father.

In all of these cases, the Figure is the object, and hence, in van Hoek's proposals, the possible binding relations should have exactly the reverse distribution from the standard cases. One might try to rescue the system by proposing some special semantic relation to be associated with subjecthood that overrides Figure-Ground relations, but that, of course, would be circular in the absence of an independently verifiable, purely semantic specification for what a subject is. Van Hoek provides no such specification.

One might attempt to supplement van Hoek's proposal by appealing to information structure effects on salience. For example, we could ensure that the relevant set of books is pre-established in the context, and that universal quantification over this set is also pre-established, and further we can ensure that the quantifier phrase is a Figure. But still the structural facts override all of these potential cues and are determinant of what the binding possibilites are. Binding from a highly salient Ground object into a pronoun in the subject position is impossible:

(51) There are a whole lot of new books on display at the convention this year and they've all got something in common: *Its initial chapter contains a synopsis of each book.

We do not want to deny that pragmatic principles may have an impact on the processing of bound variable anaphora as it is clear that this is a factor in understanding the full empirical range of effects (Ariel 1990), but such principles do not explain the empirical distribution of the phenomenon.

4 Conclusion

We have outlined a general phenomeon at the syntax-semantic interface, shown how it is cross-linguistcally valid, provided both a descriptive outline of its empirical properties and a theory of some depth explaining why those properties are as they are. We have also argued that no reasonable alternative (currently) exists. All current approaches that achieve a good level of empirical success are generative in a sense recognisable from the kind of theory we sketch here (although they may be expressed in different generative frameworks, such as Categorial Grammar (Jacobson, 1999), or Lexical Functional Grammar (Dalrymple et al., 1997)).

Returning to the core question here: does this theory require reference to non-linguistic principles of cognition? Consider again the basic principles we have used, the first being Merge:

(52) a. Lexical items are syntactic units

b. If A and B are syntactic units then Merge(A, B) = {A, B} is a syntactic unit.

This is the core structure building principle that is incorporated into a recursive definition of what a syntactic structure is. It is not implausible that a similar structure building principle is available elsewhere in cognition, perhaps operating over different units, or involving different mapping principles. Tonal music, and other generative systems like arithmetic, are obvious examples (Rohrmeier 2008).

(53) Transfer of Finite Clauses: Transfer the minimal structure containing the finite complementiser (*that* in English) to phonological and semantic computations. Once a structure has been transferred, it is no longer accessible to further syntactic computation.

The claim that this principle makes is that, even at a computational level of analysis, there is a certain periodicity to syntax. Periodicity in computation is plausibly a general natural law, going beyond domain general laws of cognition (Strogatz and Stewart 1993). However, at least currently, the particular periodicity that affects the syntactic computation appears to require reference to tense or finiteness, a phenomenon that is not reducible to other areas of cognition. It may be that further cross-linguistic investigation will provide us with a richer understanding of what the conditions on quantifier scope are, but currently, some reference to peculiarly linguistic structure is needed.

The final principle we appealed to is the following.

(54) Pronounce One Occurrence: When a single object appears at more than one position in a structure, pronounce only one instance.

This is stipulated as a language specific principle, but Chomsky (2013) has speculated that it might be understood as emerging from a particular kind of reduction of computation, perhaps minimization of the phonological computation that is required. It seems unlikely, as Chomsky notes, that this principle is functionally motivated to enhance parsing, as the absence of a phonological signal marking a grammatical dependency like a relative clause, is inimical to constructing the correct parse. Similarly, this principle applied to quantifier scope leads to an increase in grammatical ambiguity, again a property which would seem difficult to motivate on functional grounds. This suggests a non-linguistic origin for this principle, although how it applies in the linguistic system appears to be particular to that system.

We have shown that it is possible to capture a wide range of empirical effects in the relationship between syntax and semantics via a few very general principles. There are a number of hidden stipulations in the system we have sketched, that are required to ensure the right syntactic units undergo Merge, but these do not affect the general argument. These very general principles, we have suggested, may be operative elsewhere in cognition (perhaps in music and mathematics) and some may be general principles of natural law. However, it seems, at least at the moment, necessary to include some very minimal reference to peculiarly linguistic concepts. As we mentioned in the introduction, there is nothing particularly totemic about whether there are purely linguistic principles. What does seem to be important, though, is the success of the kind of theory building we have used here for language, a style of explanation that is, we think, helpful elsewhere in cognition.

Acknowledgments

This research was funded by an Arts and Humanities Research Council grant (Atomic Linguistic Elements of Phi, Grant AH/G019274/1). Many thanks also to Benjamin Bruening and Marcus Pearce for helpful discussion.

References

Adger, D. (2010). Bare resumptives. In A. Rouveret (Ed.), *Resumptives at the Interfaces*. Amsterdam: John Benjamins.

Adger, D. (2015). Syntax. *Wiley Interdisciplinary Reviews in Cognitive Science 6*, 131–147.

Ariel, M. (1990). *Accessing Noun Phrase Antecedents*. London and New York: Routledge.

Bach, E., E. Jelinek, A. Kratzer, and B. H. Partee (1995). *Quantification in Natural Languages*. Dordrecht: Kluwer Academic Publishers.

Barker, C. (2012, 2013/09/02). Quantificational binding does not require c-command. *Linguistic Inquiry 43*(4), 614–633.

Barwise, J. and R. Cooper (1981). Generalized quantifiers and natural language. *Linguistics and Philosophy 4*, 159–219.

Bruening, B. (2001). *Syntax at the Edge: Cross-Clausal Phenomena and the Syntax of Passamaquoddy*. Ph. D. thesis, MIT.

Chomsky, N. (1967). The formal nature of language. In E. Lenneberg (Ed.), *Biological Foundations of Language*, pp. 397–442. New York, N.Y.: Wiley and Sons.

Chomsky, N. (1976). Conditions on the rules of grammar. *Linguistic Analysis 2*, 303–351. Reprinted in Chomsky (1977).

Chomsky, N. (1977). *Essays on Form and Interpretation*. New York: Elsevier-North Holland.

Chomsky, N. (1995). *The Minimalist Program*. Cambridge, MA: MIT Press.

Chomsky, N. (2008). On phases. In R. Freidin, C. P. Otero, and M. L. Zubizarreta (Eds.), *Foundational Issues in Linguistic Theory*, pp. 133–166. Cambridge, MA: MIT Press.

Chomsky, N. (2013). Problems of projection. *Lingua 130*, 33 – 49.

Cole, P. (1987). The structure of internally headed relative clauses. *Natural Language and Linguistic Theory 5*(2), 277–302.

Dalrymple, M., J. Lamping, F. Pereira, and V. Saraswat (1997). Quantifiers, anaphora, and intensionality. *J. of Logic, Lang. and Inf. 6*(3), 219–273.

Embick, D. and D. Poeppel (2015). Towards a computational(ist) neurobiology of language: correlational, integrated and explanatory neurolinguistics. *Language, Cognition and Neuroscience 30*(4), 357–366.

Evans, G. (1980). Pronouns. *Linguistic Inquiry 11*(2), 337–362.

Harbour, D. (2014). Paucity, abundance, and the theory of number. *Language 90*, 185–229.

Hauser, M. D., N. Chomsky, and W. T. Fitch (2002). The faculty of language: What is it, who has it, and how did it evolve? *Science 298*, 1569–1579.

Heim, I. and A. Kratzer (1998). *Semantics in Generative Grammar*. Oxford, UK: Blackwells.

Huang, J. (1982). *Logical Relations in Chinese and the Theory of Grammar*. Ph. D. thesis, MIT, Cambridge, Massachusetts.

Jacobson, P. (1999). Towards a variable-free semantics. *Linguistics and Philosophy 22*(2), 117–184.

Kamp, H. and U. Reyle (1993). *From Discourse to Logic*. Dordrecht: D. Reidel.

Kiss, K. E. (1981). Structural relations in Hungarian, a “free” word order language. *Linguistic Inquiry 12*(2), 185–213.

Kratzer, A. (2009). Making a pronoun: Fake indexicals as windows into the properties of pronouns angelika kratzer. *Linguistic Inquiry 40*, 187–237.

Kush, D., J. Lidz, and C. Phillips (2015). Relation-sensitive retrieval: Evidence from bound variable pronouns. *Journal of Memory and Language 82*, 18–40.

Langacker, R. (1969). Pronominalization and the chain of command. In D. Reibel and S. Schane (Eds.), *Modern Studies in English*, pp. 160–186. Englewood Cliffs: Prentice-Hall.

Marr, D. (1982). *Vision*. San Francisco: Freeman and Co.

Peters, S. and D. Westerståhl (2006). *Quantifiers in Language and Logic*. Oxford: Oxford University Press.

Postal, P. (1971). *Cross-over Phenomena*. New York: Holt, Rinehart and Winston.

Rohrmeier, M. (2008). A generative grammar approach to diatonic harmonic structure. In S. Haralambos, A. Georgaki, G. Kouroupetroglou, and C. Anagnostopoulou (Eds.), *Proceedings of the 4th sound and music computing conference.*, pp. 97–100. Athens: National and Kapodistran University of Athens.

Rullmann, H. (2003). Bound-variable pronouns and the semantics of number. In B. Agbayani, P. Koskinen, and V. Samiian (Eds.), *Proceedings of the Western Conference on Linguistics: WECOL 2002.*, Fresno, CA., pp. 243–254. Department of Linguistics, California State University.

Safir, K. (2004). *The syntax of anaphora.* Oxford, UK: Oxford University Press.

Shimoyama, J. (2006). Indeterminate phrase quantification in Japanese. *Natural Language Semantics 139–173*(14), 2.

Strogatz, S. H. and I. Stewart (1993). Coupled oscillators and biological synchronization. *Scientific American, December*, 102–109.

Talmy, L. (1975). Figure and ground in complex sentences. In *Proceedings of the First Annual Meeting of the Berkeley Linguistics Society*, Volume 1, pp. 419–430.

Talmy, L. (2000). *Towards a Cognitive Semantics*. Cambdridge, MA: MIT Press.

van Hoek, K. (1996). A cognitive grammar account of bound anaphora. In E. Casad (Ed.), *Cognitive Linguistics in the Redwoods: The Expansion of a New Paradigm in Linguistics*, pp. 753–792. Berlin: De Gruyter.