[Review]

Taking Scope: The Natural Semantics of Quantifiers


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Keywords: quantifier scope, categorial grammar, Skolem term, scope parallelism

1. Introduction

In this book, Mark Steedman proposes a theory of quantification in Combinatory Categorial Grammar (CCG), a version of categorial grammar that Steedman himself has been developing in the last thirty years (see Steedman (2000) and references cited therein). Categorial grammar is a linguistic theory that has its roots in mathematical logic (Ajdukiewicz (1935), Bar-Hillel (1953), Lambek (1958)), and one of its central characteristics is the straightforward interface between syntax and semantics (Carpenter (1997), Jacobson (1999)). However, research in CCG has so far mostly focused on syntactic phenomena (such as unbounded dependencies, coordination, binding and control). Thus, a large-scale treatment of primarily semantic phenomena like that provided by the present volume is a much awaited addition to the literature.

It is clear from the introduction that the present volume is addressed to both theoretical and computational linguists, and that practical computational implementation is one of the central concerns for Steedman in developing his theory of quantification (as has always been the case with CCG). However, the main goal of the book is to propose a linguistically adequate theory of quantification. Since I take this to be the primary interest of the majority of the readers of EL as well, I focus on this aspect in

* This work was supported by the Research Fellowship of the Japan Society for the Promotion of Science under Grant No. 22–2912. I would like to thank two anonymous reviewers for very useful comments. Needless to say, all remaining errors are mine.
my review. But it is important to keep in mind that, for the above reason, in Steedman’s work (including the present one) there is always an (often implicit) tension between computational concerns and purely linguistic considerations, and crucial theoretical decisions are often guided as much by the former as by the latter, which might otherwise appear puzzling.

When viewed as a linguistic theory, Steedman’s proposal contains a number of innovative ideas, each constituting an intriguing alternative to the currently standard views on the nature of quantification in natural language (and on the syntax-semantics interface that supports it). All of these assumptions merit careful scrutiny, but due to space limitations, in the ensuing discussion I will focus on two core aspects of the proposed theory (each discussed in sections 3 and 4 below, after a review of the basic setup in section 2), where it departs most radically from previous (and/or more standardly entertained) approaches. In doing so, I aim to tease apart assumptions that are specific to CCG from those that are not. (As I discuss below in more detail, understanding this difference is crucial for accurately evaluating the relative strengths and weaknesses of the various components of the proposed theory. Unfortunately, this point is somewhat obscured in Steedman’s own discussion in the book.)

2. (Apparent) Scope Alternation for Indefinites via Skolem Specification

A central claim of the book is that, among various kinds of NPs, only the universal quantifiers every and each constitute true generalized quantifiers. Steedman justifies this claim by the observation that only the universal quantifier can truly invert scope over syntactically c-commanding expressions. Thus, (according to Steedman) in the following pair, (1a) is scopally ambiguous whereas (1b) exhibits only the surface scope reading:

(1) a. At least one referee reviewed every paper. (\(\forall \geq 1 / \exists \forall\))
   b. Every referee read at least three papers. (\# \geq 3 \forall / \forall \geq 3\)

This immediately raises the question of how to account for the (apparent) scope ambiguity in examples such as the following, with an indefinite syntactically c-commanded by a universal:

(2) Every farmer owns a donkey. (\\forall \exists / \exists \forall\)

Steedman assumes that indefinites—and, by extension, other non-universal NPs such as some Ns, two/three/… Ns, all/no/most/few Ns, etc.—denote expressions called Skolem terms and that the apparent scope ambiguity in examples like (2) arises from the non-determinism inherent in the interpretation of Skolem terms. The analysis for (2) in (3) illustrates this point. (In
the CCG notation adopted here, $X/Y$ ($X\backslash Y$) is a category that combines with a $Y$ to its right (left) to return an $X$.

(3)

\[
\begin{align*}
\text{Every farmer} & \quad \exists p. \forall y \exists x. \forall y. \exists y. \forall x. \exists y. \forall x. \exists y. \forall x. \exists y. \\
& \quad \text{owns} \quad \exists y. \forall x. \exists y. \forall x. \exists y. \forall x. \exists y. \\
& \quad \text{a donkey} \quad \exists q. \forall y \exists x. \forall y. \exists x. \forall y. \exists x. \forall y. \\
\end{align*}
\]

As in (3), the indefinite *a donkey* is translated as a (type-raised) individual-denoting expression involving a Skolem function *skolem'donkey'*. Intuitively, a Skolem function is a function which returns an arbitrary individual that satisfies some property. Thus, *skolem'donkey'* picks up an arbitrary donkey as the ‘referent’ of the indefinite. Skolem functions are thus similar to choice functions employed in the analysis of indefinites by authors such as Winter (1997, 2001) and Kratzer (1998), but unlike these authors, who take indefinites to be generally ambiguous between choice function interpretations and ordinary existential interpretations, Steedman takes indefinites to unambiguously denote Skolem terms.

The crucial component of Steedman’s analysis of indefinites is the operation of Skolem specification, which maps an unspecified Skolem term lexically encoded in the indefinite (such as *skolem'donkey'* above) to a specified Skolem term, whose interpretation depends on the environment variable(s) notated as a superscript. The environment contains all the variables bound by the quantifiers that scope over the target Skolem term in the semantic translation at the point of the derivation at which Skolem specification takes place. In (3), where Skolem specification (notated by the dotted line in the derivation) takes place after the translation for the whole sentence is built, the Skolem term is in the scope of the universal quantifier in the whole translation. This has the effect that the specified Skolem term $sk_{\text{donkey}}^{(y)}$ has variable $y$ (bound by the universal) in its environment. This yields the surface scope reading since the Skolem function which returns an arbitrary donkey varies for each farmer.

(2) has an alternative derivation in which Skolem specification takes place before the indefinite combines with a phrase containing the subject quantifier. This yields the indefinite wide-scope interpretation. The derivation is given in (4):
Here, at the point at which Skolem specification takes place, the Skolem term that translates the indefinite is not yet in the scope of the universal quantifier. Thus, the resultant specified Skolem term \( sk_{\text{donkey}} \) has an empty environment, from which it follows that it returns the same arbitrary constant individual that is a donkey as the ‘referent’ of the indefinite for each individual that the subject universal quantifier ranges over. This corresponds to the inverse scope reading.

From the above illustration, it should be clear that what determines the relative scope between the subject universal quantifier and the object indefinite is not the form of the syntactic derivation itself (which is identical in (3) and (4)), but rather, the point in the derivation at which Skolem specification is invoked. Thus, the non-standard syntactic composition adopted in the above derivations (where the subject first combines with the verb via function composition, a valid syntactic rule in CCG) has no consequences for the relative scope between the two NPs. The non-standard derivation is chosen here simply for expository convenience; as will become clear below, it is important for Steedman’s theory that both scoping possibilities are available for a syntactic analysis where the subject-verb sequence is treated as a constituent of type \( S/\text{NP} \).

A question worth dwelling upon a bit at this point is to what extent the above account of scope ambiguity is compositional. The analysis in terms of Skolem specification certainly fits very nicely with the syntax-semantics interface of CCG, which directly identifies the surface syntactic structure as the combinatoric structure. Note in particular that, as Steedman himself emphasizes, no additional syntactic representation such as LF, nor an additional storage mechanism like Cooper storage, is invoked for mediating the apparent mismatch between syntactic structure and semantic scope. However, this approach arguably violates the stricter notion of compositionality known as direct compositionality (Jacobson (1999)). According to Jacobson, direct compositionality dictates that a fully specified model-theoretic interpretation be assigned to the derived linguistic expression at each step of local syntactic composition. Translations containing unspecified Skolem terms that appear at intermediate steps in derivations like those above do not satisfy this condition since the exact model-theoretic
interpretation of the Skolem term becomes fully fixed only after Skolem specification takes place. In fact, this dependence on operational indeterminacy is precisely what gives rise to the scope ambiguity in Steedman’s account. Note also in this connection that the operation of Skolem specification is itself fundamentally syntactic (and noncompositional), in the sense that it inspects the internal structure of the logical formula that translates the whole linguistic expression and destructively modifies it by rewriting a subterm based on the syntactic scope of the relevant operators.

Let us now turn to the treatment of inverse scope for universal quantifiers to complete the discussion of basic mechanisms for deriving scope ambiguity. Steedman assumes that universal quantifiers are unlike indefinites in that they are true generalized quantifiers. In the surface-oriented syntax-semantics interface of CCG, this means that their scope is syntactically fixed. Note that, since CCG is a lexicalist theory, by saying that the scope of the quantifier is ‘syntactically’ fixed, it does not follow that the structure of the derivation alone determines the scope of the quantifier—the lexical type assignment of the quantifier itself also matters, as will become clear below. The following example, in which the inverse scope interpretation for the object quantifier is obtained, illustrates the relevant point succinctly:

(5)

Here, the object universal quantifier has a category that takes a transitive verb as an argument and returns a VP. This allows a right-branching derivation in which the verb directly combines with the object via function application and then the resultant VP (i.e. \( S \backslash NP \)) takes the subject indefinite as an argument. The scope of the quantifier (modulo the relative scope relation to an indefinite) is lexically encoded in its syntactic category: since the quantifier is of a category which takes the verb and the subject NP directly as arguments, it scopes over the two, which effectively means that it scopes over the whole sentence. Just as in the examples above in (3) and (4), the relative scope between the universal and the indefinite is indeterminate from the syntactic analysis alone, and is fixed by the nondeterministic process of Skolem specification. In (5), Skolem specification takes place.
after the whole sentence is built, which yields the universal wide-scope reading just as in (3).

3. ‘Parallel’ between Quantifier Scope and Extraction

The assumption that non-universal ‘quantifiers’ are individual-type Skolem terms whose interpretations are dependent on the non-deterministic process of Skolem specification is in principle independent of CCG. However, when combined with CCG’s strictly surface oriented syntax-semantics interface (in which the notion of syntactic constituency is considerably relaxed to deal with non-standard constituents of various sorts found in coordination and intonational phrasing; see Steedman (2000) for details), it opens the way for a radical hypothesis about the nature of quantification in natural language, according to which the scope of a (universal) quantifier (modulo the relative scope relation to indefinites and the like) is fully determined by the surface syntactic combinatorics. This leads to a further prediction that, other things being equal, quantifier scope and extraction should parallel each other, since, under this view, the (apparently) nonlocal nature of the two phenomena derives from a common source, viz. the flexible notion of syntactic constituency entertained in CCG.

Thus, nonlocal quantifier scope in examples like (6a) (in the $\forall \supset \exists$ interpretation) is accounted for via exactly the same mechanism which licenses the unbounded syntactic dependency in (6b), where the surface string Some teacher reported that the problem was found with is derived as a syntactic constituent of type $S/NP$ via a chain of function composition (in a way parallel to the derivation of Every farmer owns as a constituent of type $S/NP$ in (3) and (4)).

(6) a. Some teacher reported that the problem was found with every student.
   b. This is the book that John thought that Mary read ___.

Steedman takes the predicted parallel between quantifier scope and extraction to be essentially correct (although he acknowledges that this is a potentially controversial position), pointing to data such as the following as putative evidence for it (p. 30):

(7) a. At least one referee recommended that every paper should be accepted.
   b. *The papers that some referee said that ___ should be accepted were terrible.

According to Steedman, the unacceptability of the inverse scope reading for
(7a) is parallel to the ungrammaticality of extraction of the embedded subject in (7b) (the *that*-less variant of (7b) is of course fully acceptable, but since that example receives a special treatment in CCG in which the verb *said* directly subcategorizes for a VP, it is taken to be irrelevant for the issue under discussion).

The claim that all scoping relations of quantifiers can be mediated by the surface syntactic combinatorics of CCG is very radical, and if it can be maintained, it will constitute an alternative that is arguably much more tightly constrained than other approaches (such as ones involving LF movement or storage mechanisms of some sort). There are, however, some empirical data that cast doubt on this hypothesis. Specifically, quantifier scope and extraction do not always exhibit parallel behaviors in environments in which Steedman’s theory predicts they do.

To see this, consider the following example, in which a quantifier appears in a non-peripheral position.¹

(8) There are like ten million kinds of cheese and at least one person thinks that each kind is super delicious.

(www.tumblr.com/tagged/tasty-stuff)

This is an attested example whose intended interpretation is clearly the one in which *each* outscopes *at least one* (and it is acceptable on that interpretation according to my informants). Note that the structure of the sentence is exactly parallel to (7a). According to Steedman, (7a) lacks the inverse scope reading due to the fact that the string *at least one referee recommended that* cannot be derived as a CCG constituent that a type-raised quantifier *every paper* can take as a local argument. Thus, Steedman’s approach wrongly predicts that (8) lacks the inverse scope reading just like (7a), in a way parallel to the ungrammaticality of extraction from the subject position.

¹ It is unlikely that (8) lends itself to an analysis in terms of ‘illusory scope’ that Fox and Sauerland (1996) invoke for apparent inverse scope for examples like the following:

(i) At linguistic conferences, a grad student checks that every participant has a badge.

(Fox and Sauerland (1996: 72))

In Fox and Sauerland’s analysis, a generic quantification over situations takes widest scope, and the domain of quantification is restricted to ‘checking’ situations involving one grad student and one participant, giving rise to an interpretation (effectively indistinguishable from the ∀ > ∃ reading) that entails that each participant gets checked by some grad student or other. *Think* in its relevant meaning in (8) is arguably an individual-level predicate and hence lacks a situation variable. Thus, the ‘illusory scope’ effect along the above lines is unlikely to play any role in it. Note also that (8) involves *each* (instead of *every*), which is strictly infelicitous if the domain of quantification contains less than two individuals, again making the ‘illusory scope’ construal for this sentence unlikely.
in (7b).

This seems to suggest that Steedman’s approach to quantification is too restrictive. The grammaticality of (8) on the intended reading casts doubt on the validity of the fundamental hypothesis of his theory which purports to derive all quantifier scope possibilities with the strictly local combinatorics of CCG. The desire to abstain from powerful mechanisms such as QR, quantifying-in and Cooper storage mainly comes from considerations of computational complexity, an issue that CCG takes seriously. However, from purely linguistic considerations (which should be the primary concern if one’s goal is to propose a linguistic theory), it seems that at least the specific approach proposed by Steedman is inadequate. It should be noted in this connection that in other variants of categorial grammar, mechanisms analogous to quantifying-in and Cooper storage have been implemented fully explicitly (see, e.g. Oehrle (1994), Carpenter (1997)). Whether the phenomenon of quantification poses a fundamental problem for theories like CCG that adhere to low generative capacity is an open question that remains to be examined more carefully in future work.

4. ATB Scope Parallelism

Another case where Steedman’s theory makes a substantially different prediction from other approaches comes from the quantifier scope parallelism in ATB environments exemplified by (9):

(9) Every boy admires and every girl detests some saxophonist.

In this example, the right-node raised existential either scopes below the universal in both conjuncts or it scopes over the universal in both conjuncts, and mixed interpretations in which the relative scope relations between the

2 Another case which (potentially) poses a problem for Steedman’s approach comes from binding out of an embedded subject position in examples like the following (exhibiting the so-called ‘connectivity’ effect in copular sentences):

(i) The woman that every Englishman, admires is his, mother.

(Steedman (2012: 38))

Here, a universal quantifier scopes out of a relative clause modifying the subject—an island for extraction. Steedman explicitly states that such examples are excluded from the scope of his proposal (p. 36, section 3.6), arguing that the apparent binding of the pronoun in (i) is established by some mechanism ‘entirely external to compositional semantics.’ It is beyond the scope of this short review to evaluate the validity of this claim, but it should be noted that Jacobson (1994) proposes an analysis in a variant of categorial grammar that treats such examples essentially as a case of ordinary variable binding, employing only strictly compositional mechanisms of grammar.
existential and the universal do not match in the two conjuncts are not attested. As Steedman points out, in movement-based approaches, some sort of additional mechanism which ensures transderivational parallelism (cf. Fox (2000)) needs to be stipulated to obtain this outcome.

The scope parallelism in (9) immediately falls out in Steedman’s account, as a direct consequence of an analysis of right-node raising standard in categorial grammar and the Skolem term treatment of existentials in his proposal. (10) shows how the existential narrow-scope reading is obtained:

(10)

\[
\begin{align*}
\text{Every boy admires and every girl detests} & \quad \text{some saxophonist} \\
\lambda x. \forall y [\text{boy}^\prime y \rightarrow \text{admir}^\prime xy] \land \forall z [\text{girl}^\prime z \rightarrow \text{detests}^\prime xz] & \quad \lambda q. q (\text{skolem}^\prime \text{sax}^\prime) \\
\therefore S / NP & \quad S \setminus (S / NP)
\end{align*}
\]

Here, the two coordinated strings are both derived in the category \( S / NP \) (just as in the derivation (3) for the simpler non-coordinate example) and directly coordinated via generalized conjunction. The existential narrow-scope interpretation results from Skolem specification taking place after the existential combines with this coordinated \( S / NP \). At this point of the derivation, the Skolem term falls in the syntactic scope of the universal quantifier in both conjuncts. Thus, just like the surface scope derivation for the simpler example in (3), the existential scopes below the universal in both conjuncts, and the parallel existential narrow-scope interpretation obtains. Importantly, Steedman assumes that a Skolem term inherits all the variables that are in the environment at the point that Skolem specification takes place.\(^3\)

Since the two Skolem terms are both in the scope of (differ-

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\(^3\) This predicts that in examples like the following an intermediate scope reading \((\forall_{\text{professor}} > \exists_{\text{book}} > \forall_{\text{student}})\) does not exist:

(i) Every professor requires that every student read some book.

(Steedman (2012: 134))

Steedman claims that the apparent intermediate scope readings for examples like (i) arise from the same sort of ‘scope illusion’ effect triggered by implicit generic quantification that Fox and Sauerland (1996) invoke for scope inversion out of certain island environments (see footnote 1). I will not attempt here to determine whether this is a viable account of intermediate scope. One prediction that such an approach makes is that the intermediate scope reading will disappear if the sentence does not allow for a generic interpretation:

(ii) Yesterday, every professor required that every student read some book.

I leave it for future research to resolve whether this prediction is borne out.
universal quantifiers in the derivation in (10) (and hence the variables that these quantifiers bind are in the environments of the respective Skolem terms), both get obligatorily bound by the quantifiers.

(9) has an alternative derivation (omitted here) in which Skolem specification takes place before the existential syntactically combines with the coordinated S/\text{NP}. In this alternative derivation, the specified Skolem term has an empty environment (just as in the corresponding simpler example in (4)), and this Skolem term which refers to some arbitrary constant individual is distributed to the two conjuncts, yielding a parallel existential wide-scope interpretation.

Thus, the scope parallelism in examples like (9) is predicted in Steedman’s approach due to the fact that the operation of Skolem specification, which determines the relative scope between the universal quantifier and the existential, needs to happen either before or after the existential combines with the rest of the sentence. That these are the only available points in the derivation for Skolem specification to take place in turn follows from the fact that the coordinated expression is a full-fledged syntactic constituent of category $S/\text{NP}$, a standard assumption in the analysis of nonconstituent coordination (including right-node raising) in categorial grammar.

We may ask at this point to what extent this analysis of scope parallelism is dependent on assumptions specific to CCG. One crucial component, the constituent coordination analysis of right-node raising (and nonconstituent coordination more generally) is not specific to CCG, but is common to most variants of categorial grammar (cf. Morrill (1994), Carpenter (1997)). The assumption that existentials (and the like) translate as Skolem terms, though novel in the present work, does not depend on any specific property of CCG either. Thus, by adopting the Skolem term treatment of existentials by Steedman, the scope parallelism of the kind exemplified in (9) can be simulated in other variants of categorial grammar. Obtaining the same effect in derivational theories employing LF would presumably be a much more challenging task, mainly due to the unclarity of how to ensure the parallel specification of underspecified Skolem terms in the two conjuncts in an ATB movement environment (where the ATB extracted Skolem term would correspond to distinct syntactic objects originally appearing independently in the two conjuncts).

5. Conclusion

In this book, Steedman puts forward a very bold hypothesis that the sur-
face combinatorics of CCG is all we need to capture the scopal relations of (apparent) quantifiers. As illustrated above, when combined with the Skolem term treatment of indefinites, this hypothesis yields an elegant and overall very successful theory of quantification, which covers a wide range of data while at the same time restricting the generative capacity of the grammar below a threshold satisfying certain computational concerns. This is certainly an achievement to be valued highly, especially given that an analysis of a complex empirical phenomenon like quantification that is both explicit and restrictive (so as to make falsifiable predictions) is very rare.

But the restrictiveness of the theory, that is, the strict adherence to low generative capacity, is both a strength and a weakness, and the main thesis of the book cannot be accepted unless the empirical problem pointed out above is resolved. Calling into question the much too powerful nature of existing mechanisms (like QR and Cooper storage) is certainly a valid methodological strategy, but the book fails to provide a fully convincing alternative. We are thus left with the following big question (and perhaps the most important contribution of the present book is precisely that it invokes this question so keenly by intensely arguing for a very strong position): if surface combinatorics of CCG isn’t enough, what is? This is a difficult and deep question, and is relevant not just for CCG but for any theory of syntax and semantics regardless of specific framework. Further research is urgently needed to investigate this fundamental question opened up by the present work.

REFERENCES


[received December 14 2012, revised and accepted April 23 2013]

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