Determiner gapping as higher-order discontinuous constituency

Yusuke Kubota[1] and Robert Levine[2]

[1] Ohio State University <kubota@ling.ohio-state.edu>
[2] Ohio State University <levine@ling.ohio-state.edu>

Abstract. We argue that an approach to discontinuous constituency via prosodic lambda binding initiated by Oehrle (1994) and adopted by some subsequent authors (de Groote, 2001; Muskens, 2003; Pollard, 2011) needs to recognize higher-order prosodic variables to provide a fully systematic treatment of two recalcitrant empirical phenomena exhibiting discontinuity, namely, split gapping involving determiners and comparative subdeletion. Once we admit such higher-order prosodic variables, straightforward analyses of these phenomena immediately emerge. We take this result to provide strong support for recognizing such higher-order prosodic variables in this type of approach. We also touch on the more general issue of alternative approaches to discontinuity in categorial grammar, and suggest that an approach that recognizes (possibly higher-order) prosodic functors like the one we propose here leads to a more principled treatment of certain interactions between phenomena exhibiting complex types of discontinuity than competing approaches.

Keywords: Gapping, split gapping, split scope, comparative subdeletion, categorial grammar, discontinuous constituency

1 Introduction

An approach that mediates a flexible mapping between the combinatoric component of syntax and the surface string component by recognizing functional expressions in the latter was initiated by Oehrle (1994), and was adopted in certain subsequent variants of categorial grammar (CG) mainly due to its theoretical elegance (whereby one can relegate word order from the combinatoric component entirely to the prosodic component; see, e.g., de Groote (2001); Muskens (2003); Pollard (2011)). The original empirical motivation for this approach came from a simple and systematic treatment of quantification (of generalized quantifiers), but recently a wider range of empirical facts have been adduced to it by Kubota and Levine (2012) and Pollard and Smith (2012), which respectively deal with Gapping and the semantics of symmetrical predicates and related phenomena (the latter via the notion of 'parasitic scope' *a la* Barker (2007)). We here extend this empirical investigation one step further. While previous approaches in this tradition recognize only variables over string-type expressions, we argue that certain linguistic phenomena call for recognizing prosodic variables of a higher type.[3] Recognizing such higher-order variables enables treating types of discontinuity that are much more complex than is possible by just allowing for string-type gaps. We suggest that at least some of the cases in which the phenomena we deal with below interact with one another call for the fully general treatment of discontinuity that is made possible by generalizing the approach this way. We will point out that alternative approaches to discontinuity that are essentially descriptively equivalent to an approach that recognizes only string-type variables in the Oehrle-style setup (of which the recent proposal by Morrill et al. (2011) is representative) cannot adequately deal with such cases.

2 Split gapping with determiners

2.1 Split gapping is Gapping

Our first case involves a somewhat odd version of gapping first noted by McCawley (1993), which is exemplified by the following sentence:

(1) Too many setters are named Kelly, and shepherds Fritz.

Here, in addition to the verb, the determiner is missing from the second conjunct. We call this construction *determiner gapping*.

McCawley (1993) also noted that in determiner gapping, the verb obligatorily undergoes gapping, together with the determiner. Thus:

(2) ??Too many setters are named Kelly, and shepherds are named Fritz.

Whatever its exact nature, the reduced acceptability of (2) suggests that determiner gapping is indeed a case of Gapping, since reduced acceptability of the verb non-gapped version is found in other types of discontinuous gapping as well:

(3) a. Robin wants Leslie to win, and Terry __ Peter __.
b. ??Robin wants Leslie to win, and Terry wants Peter __.

In other respects too, determiner gapping parallels normal Gapping. Note first that, in both constructions, the relevant deletion operation (however one characterizes it theoretically) can target strings consisting of chains of verbs:

(4) a. Most professors [want to try to get] extra teaching, and most students, __ a summer job.
b. Too many professors want to try to get extra teaching, and students __ good-paying jobs, for us to cut the budget for summer.

Second, not just (mono-)transitive verbs but verbs taking multiple arguments can undergo Gapping, and this carries over to determiner gapping as well.

[3] When we say variables of higher-order type, we mean variables posited in the calculus, which can enter into hypothetical reasoning in the derivation. This shouldn't be confused with metavariables for writing functional phonologies of linguistic expressions, for which higher-order types are already present in Oehrle (1994) (cf. below).

(5) a. Robin sent a chess set to the King of Norway, and Leslie, a box of chocolates to the Queen of the Netherlands.

b. Too many men sent chess sets to the King of Norway, and women, boxes of chocolate to the Queen of the Netherlands.

Finally, there is one particularly striking parallel. In addition to examples like (1) (which may lend themselves to a simple deletion-based analysis), McCawley (1993) notes examples like the following for which simply recovering the missing material in the gapped conjunct does not yield a synonymous paraphrase:

(6) a. {No/Few/Hardly any} dog eat(s) Whiskas or cat(s) Alpo.

b. $\neq$ {No/Few/Hardly any} dog eat(s) Whiskas or {no/few/hardly any} cat(s) eat(s) Alpo.

To assign the right meaning to (6a), one has to somehow let the negation that is part of the negative quantifier scope over the disjunction. In other words, there is an apparent mismatch between the surface form and semantic scope.

This may look rather anomalous, but in fact, a precisely parallel scope mismatch is found in ordinary Gapping, as noted by Siegel (1984) and Oehrle (1987):

(7) a. Mrs. J can't live in LA and Mr. J in Boston.

b. Kim didn't play bingo or Sandy sit at home all evening.

The preferred reading for (7a) is one in which the negated modal scopes over the conjunction, i.e., the $\neg\Diamond(p \wedge q)$ interpretation. Similarly for (7b).

The following data provide further parallel between the two types of gapping:

(8) a. No positron can occupy the INner shell and electron the OUTer shell of the same atom.

b. A positron can't occupy the INner shell and some electron the OUTer shell of the same atom.

Both (8a) and (8b) correspond to $\neg\Diamond(\exists_x \psi(x) \wedge \exists_y \varrho(y))$ in meaning. So far as we are aware, Gapping is the only phenomenon in which an auxiliary scopes out of its local clause. The fact that this possibility is also realized in determiner gapping convincingly indicates that it is indeed a species of Gapping.

In view of this parallel between ordinary Gapping and determiner gapping, we propose an analysis which treats the latter as a special case of the former. For this purpose, we build on the treatment of Gapping by Kubota and Levine (2012), which is couched in a variant of categorial grammar called Hybrid Type-Logical Categorial Grammar (Hybrid TLCG). The central feature of this framework is that it recognizes both directional slashes (i.e. forward and backward slashes) familiar from standard TLCG (going back to Lambek (1958)), and a non-directional slash tied to prosodic λ-binding in more recent variants of CG (Oehrle, 1994; de Groote, 2001; Muskens, 2003; Pollard, 2011). Kubota and Levine show how the apparently anomalous scoping pattern of auxiliaries falls out straightforwardly in such a setup. In what follows, building on this analysis of Gapping, we formulate an analysis of the determiner gapping data above.

Capturing the scopal relation between negative quantifiers and disjunction in examples like (6a) requires the so-called split scope analysis of negative quantifiers like *no* and *few*, where they are decomposed into a wide-scoping sentential negation and a non-negative quantifier meaning (*no* $= \neg + \exists$, *few* $= \neg +$ **many**; cf., e.g., Jacobs (1980); Johnson (2000); Penka (2011)). To the best of our knowledge, an exact implementation of split scope in CG is still an open question. In what follows, we suggest two alternatives for implementing split scope in Hybrid TLCG. The two approaches have more or less the same empirical coverage, but they differ in how exactly the decomposition of the two meaning components of negative quantifiers is mediated. The simpler approach that we present first involves an empty operator and a diacritic syntactic category, thereby directly separating the two meaning components in the combinatoric structure of the sentence, whereas the more sophisticated approach encodes the scope split directly within the lexicon, by treating negative determiners as lexically type-raised determiners. As we show below, the apparent scope anomaly of data like (6a) becomes a non-anomaly in both approaches, once the analysis of negative quantifiers is combined with an analysis of determiner gapping which is a straightforward extension of the Kubota-Levine analysis.

2.2 Kubota and Levine's (2012) analysis of Gapping

The key analytic idea of Kubota and Levine's (2012) analysis of Gapping is that Gapping involves coordinating two (or more) sentences in which the verb is missing in the middle. This involves explicitly modelling such gapped sentences which essentially manifest discontinuous constituency as conjoinable categories. For this purpose, Kubota and Levine exploit the 'hybrid' nature of their calculus, which is equipped with rules for Elimination and Introduction for both directional slashes ($/$ and $\backslash$) and the order-insensitive non-directional slash (notated as $|$). The following is the complete set of inference rules of Hybrid TLCG:

(9)

Connective	Introduction	Elimination
$/$	$\dfrac{\dfrac{\begin{array}{ccc} \vdots & \underline{[\varphi;\ x;\ A]^n} & \vdots \\ \vdots & \vdots & \vdots \end{array}}{\mathsf{b} \circ \varphi;\ \mathscr{F};\ B}}{\mathsf{b};\ \lambda x.\mathscr{F};\ B/A}\ /\mathrm{I}^n$	$\dfrac{\mathsf{a};\ \mathscr{F};\ A/B \quad \mathsf{b};\ \mathscr{G};\ B}{\mathsf{a} \circ \mathsf{b};\ \mathscr{F}(\mathscr{G});\ A}\ /\mathrm{E}$
$\backslash$	$\dfrac{\dfrac{\begin{array}{ccc} \vdots & \underline{[\varphi;\ x;\ A]^n} & \vdots \\ \vdots & \vdots & \vdots \end{array}}{\varphi \circ \mathsf{b};\ \mathscr{F};\ B}}{\mathsf{b};\ \lambda x.\mathscr{F};\ A\backslash B}\ \backslash\mathrm{I}^n$	$\dfrac{\mathsf{b};\ \mathscr{G};\ B \quad \mathsf{a};\ \mathscr{F};\ B\backslash A}{\mathsf{b} \circ \mathsf{a};\ \mathscr{F}(\mathscr{G});\ A}\ \backslash\mathrm{E}$

$$
| \qquad \dfrac{\dfrac{\begin{array}{ccc} \vdots & \underline{[\varphi;\, x;\, A]^n} & \vdots \\ \vdots & \vdots & \vdots \end{array}}{\mathsf{b};\ \mathscr{F};\ B}}{\lambda\varphi.\mathsf{b};\ \lambda x.\mathscr{F};\ B|A}\,|\mathrm{I}^n \qquad\qquad \dfrac{\mathsf{a};\ \mathscr{F};\ A|B \quad \mathsf{b};\ \mathscr{G};\ B}{\mathsf{a(b)};\ \mathscr{F}(\mathscr{G});\ A}\,|\mathrm{E}
$$

The difference between /,\ and | is that while the rules for /,\ refer to the phonological forms of the input and output strings (so, for example, the applicability of the /I rule is conditioned on the presence of the phonology of the hypothesis φ on the right periphery of the phonology of the input $\mathsf{b} \circ \varphi$), the rules for | are not constrained that way. For reasoning involving |, the phonological terms themselves fully specify the ways in which the output phonology is constructed from the input phonologies. Specifically, for |, the phonological operations associated with the Introduction and Elimination rules mirror exactly the semantic operations for these rules: function application and λ-abstraction. Thus, the order of the premises in the Elimination rules isn't relevant for any of these connectives; linear order is recorded in the phonological terms of the linguistic expressions (and not in the forms of the proofs) for reasoning involving / and \.

As shown by Oehrle (1994), hypothetical reasoning with a mode of implication associated with λ-binding enables a straightforward and formally explicit implementation of Montague's (1973) quantifying-in, as illustrated in (10):

(10)

$$
\dfrac{\begin{array}{l}\lambda\sigma.\sigma(\mathsf{everyone});\\ \forall_{\mathbf{person}};\\ \mathrm{S}|(\mathrm{S}|\mathrm{NP})\end{array} \quad \dfrac{\dfrac{\begin{array}{l}\lambda\sigma.\sigma(\mathsf{someone});\\ \exists_{\mathbf{person}};\\ \mathrm{S}|(\mathrm{S}|\mathrm{NP})\end{array} \quad \dfrac{\dfrac{\dfrac{\begin{bmatrix}\varphi_2;\\ y;\mathrm{NP}\end{bmatrix}^2 \quad \dfrac{\begin{array}{l}\mathsf{talked} \circ \mathsf{to};\\ \mathbf{talk\text{-}to};\\ (\mathrm{NP}\backslash\mathrm{S})/\mathrm{NP}\end{array} \quad \begin{bmatrix}\varphi_1;\\ x;\mathrm{NP}\end{bmatrix}^1}{\begin{array}{l}\mathsf{talked} \circ \mathsf{to} \circ \varphi_1;\\ \mathbf{talk\text{-}to}(x);\mathrm{NP}\backslash\mathrm{S}\end{array}}}{\begin{array}{l}\varphi_2 \circ \mathsf{talked} \circ \mathsf{to} \circ \varphi_1;\\ \mathbf{talk\text{-}to}(x)(y);\mathrm{S}\end{array}} \quad \begin{array}{l}\mathsf{yesterday};\\ \mathbf{yest};\mathrm{S}\backslash\mathrm{S}\end{array}}{\begin{array}{l}\varphi_2 \circ \mathsf{talked} \circ \mathsf{to} \circ \varphi_1 \circ \mathsf{yesterday};\\ \mathbf{yest}(\mathbf{talk\text{-}to}(x)(y));\mathrm{S}\end{array}}}{\begin{array}{l}\lambda\varphi_2.\varphi_2 \circ \mathsf{talked} \circ \mathsf{to} \circ \varphi_1 \circ \mathsf{yesterday};\\ \lambda y.\mathbf{yest}(\mathbf{talk\text{-}to}(x)(y));\mathrm{S}|\mathrm{NP}\end{array}}}{\begin{array}{l}\mathsf{someone} \circ \mathsf{talked} \circ \mathsf{to} \circ \varphi_1 \circ \mathsf{yesterday};\\ \exists_{\mathbf{person}}(\lambda y.\mathbf{yest}(\mathbf{talk\text{-}to}(x)(y)));\mathrm{S}\end{array}}}{\begin{array}{l}\lambda\varphi_1.\mathsf{someone} \circ \mathsf{talked} \circ \mathsf{to} \circ \varphi_1 \circ \mathsf{yesterday};\\ \lambda x.\exists_{\mathbf{person}}(\lambda y.\mathbf{yest}(\mathbf{talk\text{-}to}(x)(y)));\mathrm{S}|\mathrm{NP}\end{array}}}{\begin{array}{l}\mathsf{someone} \circ \mathsf{talked} \circ \mathsf{to} \circ \mathsf{everyone} \circ \mathsf{yesterday};\\ \forall_{\mathbf{person}}(\lambda x.\exists_{\mathbf{person}}(\lambda y.\mathbf{yest}(\mathbf{talk\text{-}to}(x)(y))));\mathrm{S}\end{array}}
$$

Quantifiers are entered in the lexicon in the S|(S|NP) type, with the standard generalized quantifier meaning and a phonology that is a higher-order function over strings of type $(st \to st) \to st$ (with st the type of strings), which 'lowers' the quantifier string in the position in the sentence (bound by the λ-operator in the phonology) corresponding to the semantic variable bound. As in Montague's quantifying-in, the order in which the quantifier combines with the sentence that it lowers into determines its scope. Thus, the above derivation yields the inverse scope interpretation; if the object quantifier is introduced first in the derivation, we get the surface scope interpretation.

The treatment of discontinuous constituency by recognizing functional phonologies has wider empirical applications than just quantification. Kubota and Levine (2012) demonstrate this via an analysis of Gapping. Since expressions containing medial gaps can be modelled via hypothetical reasoning with the vertical slash |, expressions like *Robin __ a book* in (11) can be directly analyzed as a sentence missing a transitive verb, of category S|TV (with TV = (NP\S)/NP), as in (12).

(11) Leslie bought a CD, and Robin, a book.

(12)

$$\dfrac{\lambda\sigma_1.\sigma_1(\mathsf{a}\circ\mathsf{book});\ \exists_{\mathbf{book}};\ \mathrm{S}|(\mathrm{S}|\mathrm{NP}) \qquad \dfrac{\dfrac{\mathsf{robin};\ \mathbf{r};\ \mathrm{NP} \qquad \dfrac{[\varphi_1; P; \mathrm{VP}/\mathrm{NP}]^1 \qquad [\varphi_2; x; \mathrm{NP}]^2}{\varphi_1\circ\varphi_2;\ P(x);\ \mathrm{VP}}}{\mathsf{robin}\circ\varphi_1\circ\varphi_2;\ P(x)(\mathbf{r});\ \mathrm{S}}}{\lambda\varphi_2.\mathsf{robin}\circ\varphi_1\circ\varphi_2;\ \lambda x.P(x)(\mathbf{r});\ \mathrm{S}|\mathrm{NP}}}{\dfrac{\mathsf{robin}\circ\varphi_1\circ\mathsf{a}\circ\mathsf{book};\ \exists_{\mathbf{book}}(\lambda x.P(x)(\mathbf{r}));\ \mathrm{S}}{\lambda\varphi_1.\mathsf{robin}\circ\varphi_1\circ\mathsf{a}\circ\mathsf{book};\ \lambda P.\exists_{\mathbf{book}}(\lambda x.P(x)(\mathbf{r}));\ \mathrm{S}|(\mathrm{VP}/\mathrm{NP})}}$$

By binding the hypothetically assumed TV at the last step of (12), we obtain an expression with a functional phonology (of type $st \to st$), where the phonological variable φ_1 keeps track of the position of the missing verb.

For coordinating such $st \to st$ functions (phonologically), Kubota and Levine introduce the following Gapping-specific lexical entry for the conjunction:

(13) $\lambda\sigma_2\lambda\sigma_1\lambda\varphi[\sigma_1(\varphi)\circ\mathsf{and}\circ\sigma_2(\varepsilon)];\ \lambda\mathscr{W}\lambda\mathscr{V}.\mathscr{V}\sqcap\mathscr{W};\ (\mathrm{S}|\mathrm{TV})|(\mathrm{S}|\mathrm{TV})|(\mathrm{S}|\mathrm{TV})$

Syntactically, (13) coordinates two sentences missing the main verb (i.e. S|TV) to produce a larger expression of the same type, instantiating the general like-category coordination schema; correspondingly, the semantics is that of generalized conjunction, again conforming to the general treatment of coordination. The only slight complication is in the phonology, where it is specified that the 'gap' position of the first conjunct is retained (so that the main verb can 'lower' into this position at a later step in the derivation) while the corresponding gap in the second conjunct is closed off by feeding an empty string ε to it.

With this conjunction lexical entry, (11) can be derived as in (14):

(14)

$$\dfrac{\begin{array}{l}\mathsf{bought};\\ \mathbf{buy};\\ \mathrm{TV}\end{array} \qquad \dfrac{\begin{array}{l}\quad\vdots\quad\vdots\\ \lambda\varphi_1.\mathsf{leslie}\circ\varphi_1\circ\\ \mathsf{a}\circ\mathsf{CD};\\ \lambda Q.\exists_{\mathbf{CD}}(\lambda y.Q(y)(\mathbf{l}));\\ \mathrm{S}|\mathrm{TV}\end{array} \qquad \dfrac{\begin{array}{l}\lambda\sigma_2\lambda\sigma_1\lambda\varphi_0.\sigma_1(\varphi_0)\circ\\ \mathsf{and}\circ\sigma_2(\varepsilon);\\ \lambda\mathscr{W}\lambda\mathscr{V}.\mathscr{V}\sqcap\mathscr{W};\\ (\mathrm{S}|\mathrm{TV})|(\mathrm{S}|\mathrm{TV})|(\mathrm{S}|\mathrm{TV})\end{array} \qquad \begin{array}{l}\quad\vdots\quad\vdots\\ \lambda\varphi_1.\mathsf{robin}\circ\varphi_1\circ\mathsf{a}\circ\mathsf{book};\\ \lambda P.\exists_{\mathbf{book}}(\lambda x.P(x)(\mathbf{r}));\\ \mathrm{S}|\mathrm{TV}\end{array}}{\begin{array}{l}\lambda\sigma_1\lambda\varphi_0.\sigma_1(\varphi_0)\circ\mathsf{and}\circ\mathsf{robin}\circ\varepsilon\circ\mathsf{a}\circ\mathsf{book};\\ \lambda\mathscr{V}.\mathscr{V}\sqcap\lambda P.\exists_{\mathbf{book}}(\lambda x.P(x)(\mathbf{r}));(\mathrm{S}|\mathrm{TV})|(\mathrm{S}|\mathrm{TV})\end{array}}}{\begin{array}{l}\lambda\varphi_0[\mathsf{leslie}\circ\varphi_0\circ\mathsf{a}\circ\mathsf{CD}\circ\mathsf{and}\circ\mathsf{robin}\circ\varepsilon\circ\mathsf{a}\circ\mathsf{book}];\\ \lambda Q.\exists_{\mathbf{CD}}(\lambda y.Q(y)(\mathbf{l}))\sqcap\lambda P.\exists_{\mathbf{book}}(\lambda x.P(x)(\mathbf{r}));\mathrm{S}|\mathrm{TV}\end{array}}}{\begin{array}{l}\mathsf{leslie}\circ\mathsf{bought}\circ\mathsf{a}\circ\mathsf{CD}\circ\mathsf{and}\circ\mathsf{robin}\circ\varepsilon\circ\mathsf{a}\circ\mathsf{book};\\ \exists_{\mathbf{CD}}(\lambda y.\mathbf{buy}(y)(\mathbf{l}))\wedge\exists_{\mathbf{book}}(\lambda x.\mathbf{buy}(x)(\mathbf{r}));\mathrm{S}\end{array}}$$

In this analysis by Kubota and Levine, the role of both directional and nondirectional implication is crucial: the gapped sentence S|TV (= S|((NP\S)/NP)), which is associated with the functional phonology $\lambda\varphi_1.\mathsf{robin} \circ \varphi_1 \circ \mathsf{a} \circ \mathsf{book}$, explicitly keeps track of the position of the medial gap via |, and, since what's missing is a transitive verb (i.e. (NP\S)/NP, indicating explicitly the directions in which it looks for its two arguments via / and \), the subject and the object appear in the right order in the string part of this functional phonology. Note in particular that in a uni-implication systems like ACG and Lambda Grammar, keeping track of the right word order becomes a virtually intractable problem.[4]

We omit the analysis of scope interactions between auxiliaries and Gapping, but the key idea should already be clear from the above analysis: the auxiliary wide scope interpretations for sentences like those in (7) fall out in this analysis since auxiliaries are introduced in the tectogrammatical derivation essentially in the same way as main verbs in (14) above, at a point after the coordinate structure is built. The structure of the derivation determines the relative scope between the auxiliary and coordination, thus, the former scopes over the latter.[5] The mismatch between the surface form of the sentence and the semantic scope is due to the morpho-syntactic requirement of the Gapping construction that the verb (or the auxiliary) be pronounced only once and within the first conjunct, as specified in the lexical entry for the Gapping-type conjunction in (13).

2.3 Split scope in Hybrid TLCG

We propose that determiner gapping is just a special case of discontinuous gapping in which both the verb and the determiner are gapped. The negation wide scope is obtained for examples like (6a) since the negative determiner, being gapped, takes scope over the whole coordinate structure. Thus, the apparently

[4] A reviewer expressed a concern that this analysis would overgenerate examples such as (†) **Larry thinks Sue is nice and Sue ~~thinks~~ Larry is funny* and (‡) **John gave a book to Mary and Peter ~~gave a book to Mary~~*. However, independent processing-oriented explanations exist for such examples. The difficulty of interpreting the NP NP V sequence in (†) without being led to a garden path by taking just the NP NP substring to be a gapped constituent can be dramatically ameliorated with an explicit complementizer (*... and Sue that Larry is funny*). For (‡), an alternative parse *John gave a book to [Mary and Peter]* seems to create a practically irrecoverable garden path effect. (‡) additionally violates a functional felicity conditions on Gapping which requires at least two contrasting elements in the two clauses (Kuno, 1976).

[5] However, as noted by Oehrle (1987), in at least some cases a distributive, auxiliary narrow-scope reading is available in such examples, and in order to derive this reading, it becomes necessary to reduce the prosodic type of the auxiliary from $(st \to st) \to st$ to st. This type of proof crucially requires inferences involving directional and non-directional slashes to interact with one another (Kubota and Levine, 2012, 2013). Similar reduction of a (phonologically) higher-order scopal operator to a lower type is required for licensing distributive readings for generalized quantifiers as well (Kubota and Levine, 2013) (which can be found in the Gapping context as well, as in *Chris set a problem for her logic exam, and Terry for his cell anatomy class*), providing further empirical evidence for the present hybrid implication system.

anomalous scoping pattern is a predicted consequence of the analysis, much in the same way that the wide scope auxiliary in (7) is immediately predicted in Kubota and Levine's (2012) like-category coordination analysis of Gapping.

To formulate an explicit analysis, we need to work out the relevant details of the mechanism for split scope. We first illustrate a more or less direct implementation of the 'LF decomposition' analysis widely entertained in the literature. The key assumption of this approach is that negative quantifiers are semantically decomposed into two meaning components at the level of representation relevant for semantic interpretation. For example, *no* decomposes into an existential quantifier and sentential negation that scopes above it. The challenge is how to treat the interdependence between these two meaning components and make sure that they together realize as one morpheme *no* in the overt string.

We here propose to model the existential quantifier part via a prosodically empty operator which is constrained to occur in the scope of the overt negation morpheme *no*. To capture the interdependence between the covert existential and the overt negation, we posit the syntactic category $\mathrm{S_{neg}}$, which designates a sentence containing the covert existential somewhere inside and which is waiting to be 'scoped over' by the overt negation *no*. Thus, the covert existential has the following lexical entry, which is identical to overt existential quantifiers except that it returns $\mathrm{S_{neg}}$ instead of S. Phonologically, expressions with syntactic category $\mathrm{S_{neg}}$ have a $st \to st$ phonology which keeps track of the 'gap' position that the higher negation morpheme *no* lowers into.

(15) $\lambda\varphi_1\lambda\sigma\lambda\varphi_2.\sigma(\varphi_2 \circ \varphi_1);\ \lambda P.\exists_P;\ \mathrm{S_{neg}}|(\mathrm{S}|\mathrm{NP})|\mathrm{N}$

The negation morpheme has the following lexical entry:

(16) $\lambda\sigma.\sigma(\mathsf{no});\ \neg;\ \mathrm{S}|\mathrm{S_{neg}}$

It takes a $\mathrm{S_{neg}}$ as argument and returns an ordinary S. Semantically, it contributes sentential negation. Phonologically, it lowers the phonology *no* into the determiner 'gap' position introduced by the empty existential.

A simple sentence containing a negative quantifier is then analyzed as follows:

(17)

$$\dfrac{\lambda\sigma.\sigma(\mathsf{no});\ \neg;\ \mathrm{S}|\mathrm{S_{neg}} \qquad \dfrac{\dfrac{\begin{array}{c}\lambda\varphi_1\lambda\sigma\lambda\varphi_2.\sigma(\varphi_2 \circ \varphi_1);\\ \lambda P.\exists_P;\mathrm{S_{neg}}|(\mathrm{S}|\mathrm{NP})|\mathrm{N}\end{array} \quad \begin{array}{c}\mathsf{fish};\\ \mathbf{fish};\mathrm{N}\end{array}}{\lambda\sigma\lambda\varphi_2.\sigma(\varphi_2 \circ \mathsf{fish});\ \exists_{\mathbf{fish}};\ \mathrm{S_{neg}}|(\mathrm{S}|\mathrm{NP})} \qquad \begin{array}{c}\vdots \quad \vdots\\ \lambda\varphi.\varphi \circ \mathsf{walks};\\ \mathbf{walk};\mathrm{S}|\mathrm{NP}\end{array}}{\lambda\varphi_2.\varphi_2 \circ \mathsf{fish} \circ \mathsf{walks};\ \exists_{\mathbf{fish}}(\mathbf{walk});\ \mathrm{S_{neg}}}}{\mathsf{no} \circ \mathsf{fish} \circ \mathsf{walks};\ \neg\exists_{\mathbf{fish}}(\mathbf{walk});\ \mathrm{S}}$$

As shown here, the covert existential takes scope just like ordinary quantifiers do, but returns the category $\mathrm{S_{neg}}$ instead. The overt negation then takes this category as an argument to semantically scope over the whole sentence and prosodically lower itself into the determiner 'gap' position introduced by the covert existential. This yields the right pairing of surface form and interpretation, embodying the idea of split scope directly in the combinatoric structure.

With this analysis of split scope, the determiner gapping example (6a) can be analyzed as coordination of expressions of category $\mathrm{S_{neg}|TV}$, that is, sentences in which both the verb and the overt negative determiner are missing. With hypothetical reasoning, deriving such an expression is straightforward, as in (18):

(18)

$$
\dfrac{
\dfrac{
\dfrac{
\begin{array}{l}\lambda\varphi_1\lambda\sigma\lambda\varphi_2.\sigma(\varphi_2 \circ \varphi_1);\\ \lambda P.\exists_P;\mathrm{S_{neg}|(S|NP)|N}\end{array}
\quad
\begin{array}{l}\mathsf{dog};\\ \mathbf{dog};\mathrm{N}\end{array}
}{
\begin{array}{l}\lambda\sigma\lambda\varphi_2.\sigma(\varphi_2 \circ \mathsf{dog});\\ \exists_{\mathbf{dog}};\mathrm{S_{neg}|(S|NP)}\end{array}
}
\quad
\dfrac{
\dfrac{
[\varphi_2; x; \mathrm{NP}]^2
\quad
\dfrac{[\varphi_1; P; \mathrm{TV}]^1 \quad \mathsf{whiskas};\ \mathbf{w};\ \mathrm{NP}}{\varphi_1 \circ \mathsf{whiskas};\ P(\mathbf{w});\ \mathrm{VP}}
}{
\varphi_2 \circ \varphi_1 \circ \mathsf{whiskas};\ P(\mathbf{w})(x);\ \mathrm{S}
}
}{
\lambda\varphi_2.\varphi_2 \circ \varphi_1 \circ \mathsf{whiskas};\ \lambda x.P(\mathbf{w})(x);\ \mathrm{S|NP}
}
}{
\lambda\varphi_2.\varphi_2 \circ \mathsf{dog} \circ \varphi_1 \circ \mathsf{whiskas};\ \exists_{\mathbf{dog}}(\lambda x.P(\mathbf{w})(x));\ \mathrm{S_{neg}}
}
}{
\lambda\varphi_1\lambda\varphi_2.\varphi_2 \circ \mathsf{dog} \circ \varphi_1 \circ \mathsf{whiskas};\ \lambda P.\exists_{\mathbf{dog}}(\lambda x.P(\mathbf{w})(x));\ \mathrm{S_{neg}|TV}
}
$$

Or then takes two such expressions as arguments and retains only the gap of the first conjunct. This is only a slight generalization of the Gapping-type conjunction introduced above. The rest of the derivation is shown in (19).

(19)

$$
\dfrac{
\begin{array}{l}\lambda\sigma.\sigma(\mathsf{no});\\ \neg;\mathrm{S|S_{neg}}\end{array}
\quad
\dfrac{
\begin{array}{l}\mathsf{eats};\\ \mathbf{eat};\\ \mathrm{TV}\end{array}
\quad
\dfrac{
\begin{array}{c}\vdots \quad \vdots\\ \begin{array}{l}\lambda\varphi_1\lambda\varphi_2.\varphi_2 \circ \mathsf{dog}\\ \circ\varphi_1 \circ \mathsf{whiskas};\\ \lambda P.\exists_{\mathbf{dog}}(P(\mathbf{w}));\\ \mathrm{S_{neg}|TV}\end{array}\end{array}
\quad
\dfrac{
\begin{array}{l}\lambda\sigma_2\lambda\sigma_1\lambda\varphi_1\lambda\varphi_2.\\ \sigma_1(\varphi_1)(\varphi_2) \circ \mathsf{or} \circ \sigma_2(\varepsilon)(\varepsilon);\\ \lambda V\lambda W.W \sqcup V;X|X|X\end{array}
\quad
\begin{array}{c}\vdots \quad \vdots\\ \begin{array}{l}\lambda\varphi_1\lambda\varphi_2.\varphi_2 \circ \mathsf{cat}\\ \circ\varphi_1 \circ \mathsf{alpo};\\ \lambda P.\exists_{\mathbf{cat}}(P(\mathbf{a}));\\ \mathrm{S_{neg}|TV}\end{array}\end{array}
}{
\begin{array}{l}\lambda\sigma_1\lambda\varphi_1\lambda\varphi_2.\sigma_1(\varphi_1)(\varphi_2) \circ \mathsf{or} \circ \mathsf{cat} \circ \mathsf{alpo};\\ \lambda W.W \sqcup \lambda P.\exists_{\mathbf{cat}}(P(\mathbf{a}));\mathrm{(S_{neg}|TV)|(S_{neg}|TV)}\end{array}
}
}{
\begin{array}{l}\lambda\varphi_1\lambda\varphi_2.\varphi_2 \circ \mathsf{dog} \circ \varphi_1 \circ \mathsf{whiskas} \circ \mathsf{or} \circ \mathsf{cat} \circ \mathsf{alpo};\\ \lambda P.\exists_{\mathbf{dog}}(P(\mathbf{w})) \sqcup \lambda P.\exists_{\mathbf{cat}}(P(\mathbf{a}));\mathrm{S_{neg}|TV}\end{array}
}
}{
\begin{array}{l}\lambda\varphi_2.\varphi_2 \circ \mathsf{dog} \circ \mathsf{eats} \circ \mathsf{whiskas} \circ \mathsf{or} \circ \mathsf{cat} \circ \mathsf{alpo};\\ \exists_{\mathbf{dog}}(\mathbf{eat}(\mathbf{w})) \vee \exists_{\mathbf{cat}}(\mathbf{eat}(\mathbf{a}));\mathrm{S_{neg}}\end{array}
}
}{
\begin{array}{l}\mathsf{no} \circ \mathsf{dog} \circ \mathsf{eats} \circ \mathsf{whiskas} \circ \mathsf{or} \circ \mathsf{cat} \circ \mathsf{alpo};\\ \neg[\exists_{\mathbf{dog}}(\mathbf{eat}(\mathbf{w})) \vee \exists_{\mathbf{cat}}(\mathbf{eat}(\mathbf{a}))];\mathrm{S}\end{array}
}
$$

After the whole coordinate structure is built, the verb and *no* are lowered into their respective positions in the first conjunct. Since the negative morpheme scopes over the whole coordinate structure in the tectogrammatical structure reflecting the combinatorial order, the negation wide scope reading is obtained.

2.4 Lexical treatment of split scope via type-raised quantifiers

The analysis of split scope above is a fairly straightforward implementation of the 'LF decomposition' analysis. It works fine and extends straightforwardly to the treatment of apparent scope anomaly in determiner gapping, but note that it involves some ad-hoc assumptions. An empty operator like the covert existential posited above should be avoided if possible, and the newly introduced syntactic category $\mathrm{S_{neg}}$ is a purely diacritic device, having no motivation other than to control the distribution of the overt and covert operators that are stipulated to correlate with one another. Moreover, without $\mathrm{S_{neg}}$, there is a straightforward one-to-one mapping between syntactic and prosodic types such that the prosodic type of any syntactic category is transparently reflected in the level of embedding involving the vertical slash (so, for example, any expression of syntactic type X|(Y|Z), with X–Z all atomic or involving only the directional slashes, is of type $(st \to st) \to st$). The syntactically atomic category $\mathrm{S}_{\mathrm{neg}}$ disrupts this neat correspondence between syntactic and prosodic types, since, despite being syntactically atomic, it has a functional, $st \to st$ phonological type.

Eliminating these ad-hoc assumptions would thus be desirable, and it is indeed possible to do away with the diacritic syntactic category $\mathrm{S}_{\mathrm{neg}}$, by lexically encoding the two meaning components of negative quantifiers within a single entry. This involves specifying the scope of the higher negation and the lower existential separately within the lexical entry for the negative determiner, and requires treating the determiners forming negative quantifiers as lexically type-raised determiners. In the present setup, determiners take their nominal arguments to become quantifiers, thus they are of type S|(S|NP)|N. Negative determiners are lexically type-raised over S on this category, thus, by taking Det to abbreviate S|(S|NP)|N, they are of type S|(S|Det). Semantically, this lexically type-raised determiner feeds an ordinary positive quantifier meaning to its argument, thus saturating the determiner-type variable position of its argument, and additionally contributes sentential negation which scopes over the whole sentence.

Thus, by lexically type-raising the determiner, the separate scoping positions of the two meaning components of negative quantifiers can be encoded fully lexically. What remains to be worked out is the phonology of the higher order determiner. Since ordinary quantificational determiners are of type $st \to ((st \to st) \to st)$, the prosodic type of this type-raised determiner is $((st \to ((st \to st) \to st)) \to st) \to st$. In other words, the phonology of the type-raised determiner has to be specified in such a way that, by binding the prosodic variable of type $st \to ((st \to st) \to st)$ of ordinary determiners in the S|Det category that it takes as an argument, we obtain the right surface string in which the string phonology of the negative determiner appears in the right position. The right form of this higher-order phonology of a type-raised determiner can be inferred from the phonological term that is assigned to a syntactically type-raised ordinary determiner. This is shown in the following derivation, where a determiner whose phonology is built from the string c is type-raised to the syntactic category S|(S|Det), with the corresponding higher-order phonology:

(20)
$$\dfrac{\dfrac{\lambda\varphi\lambda\sigma.\sigma(\mathsf{c}\circ\varphi);\ \gamma;\ \mathrm{Det} \quad [\rho;\mathscr{P};\mathrm{S|Det}]^1}{\rho(\lambda\varphi\lambda\sigma.\sigma(\mathsf{c}\circ\varphi));\ \mathscr{P}(\gamma);\ \mathrm{S}}}{\lambda\rho.\rho(\lambda\varphi\lambda\sigma.\sigma(\mathsf{c}\circ\varphi));\ \lambda\mathscr{P}.\mathscr{P}(\gamma);\ \mathrm{S|(S|Det)}}$$

By replacing the string c with no, we obtain the right phonology for the negative determiner. Thus, putting together the phonology, semantics and the syntactic category of negative determiners, we have the following lexical entry:

(21) $\lambda\rho.\rho(\lambda\varphi\lambda\sigma.\sigma(\mathsf{no}\circ\varphi));\ \lambda\mathscr{P}.\neg\mathscr{P}(\exists);\ \mathrm{S|(S|Det)}$

The derivation for a sentence with a negative quantifier then goes as follows:

(22)

$$\dfrac{\lambda\rho.\rho(\lambda\varphi\lambda\sigma.\sigma(\mathsf{no}\circ\varphi));\ \lambda\mathscr{P}.\neg\mathscr{P}(\exists); \mathrm{S}|(\mathrm{S}|\mathrm{Det}) \qquad \dfrac{\dfrac{\dfrac{[\tau;\mathscr{F};\mathrm{Det}]^1 \quad \mathsf{fish};\ \mathbf{fish};\ \mathrm{N}}{\tau(\mathsf{fish});\ \mathscr{F}(\mathbf{fish});\ \mathrm{S}|(\mathrm{S}|\mathrm{NP})} \quad \lambda\varphi.\varphi\circ\mathsf{walks};\ \mathbf{walk};\ \mathrm{S}|\mathrm{NP}}{\tau(\mathsf{fish})(\lambda\varphi.\varphi\circ\mathsf{walks});\ \mathscr{F}(\mathbf{fish})(\mathbf{walk});\ \mathrm{S}}}{\lambda\tau.\tau(\mathsf{fish})(\lambda\varphi.\varphi\circ\mathsf{walks});\ \lambda\mathscr{F}.\mathscr{F}(\mathbf{fish})(\mathbf{walk});\ \mathrm{S}|\mathrm{Det}}}{\mathsf{no}\circ\mathsf{fish}\circ\mathsf{walks};\ \neg\exists_{\mathbf{fish}}\mathbf{walk};\ \mathrm{S}}$$

The derivation proceeds by first assuming a hypothetical determiner in the position that the negative determiner lowers into later. After the whole sentence is built, this hypothesis is bound and the resultant expression is of the right type to be given as an argument to the negative determiner. Note in particular that the right surface string is obtained by applying the higher-order functional phonology of the negative determiner to its argument, itself of a functional phonological type looking for a determiner phonology to return a string.

Just as in the analysis in the previous section, determiner gapping is then treated as a case of multiple gapping involving both the verb and the determiner. The only complication here is that the 'gap' corresponding to the determiner is of a higher-order type prosodically, so an identity element of this higher-order phonological type needs to be fed to the second conjunct. This 'empty determiner phonology' can be modelled on the phonology of ordinary determiners by replacing the string part of the phonological term with an empty string. Thus:

(23) $\varepsilon_{\mathsf{d}} =_{def} \lambda\varphi\lambda\sigma.\sigma(\varepsilon\circ\varphi) = \lambda\varphi\lambda\sigma.\sigma(\varphi)$

The lexical entry for the conjunction word can then be written as in (24), generalizing the Gapping-type conjunction entry to the S|Det|TV type:

(24) $\lambda\rho_2\lambda\rho_1\lambda\varphi\lambda\sigma.\rho_1(\varphi)(\sigma)\circ\mathsf{and}\circ\rho_2(\varepsilon)(\varepsilon_{\mathsf{d}});\ \sqcap;\ \mathbf{GC}(\mathrm{S}|\mathrm{Det}|\mathrm{TV})$
where $\mathbf{GC}(A) = A|A|A$ for any syntactic type A

Expressions that are of the right type to be coordinated by this conjunction category can be derived via hypothetical reasoning in the usual way:

(25)

$$\dfrac{\dfrac{\dfrac{\dfrac{[\tau;\mathscr{F};\mathrm{Det}]^3 \quad \mathsf{dog};\ \mathbf{dog};\ \mathrm{N}}{\tau(\mathsf{dog});\ \mathscr{F}(\mathbf{dog});\ \mathrm{S}|(\mathrm{S}|\mathrm{NP})} \quad \dfrac{\dfrac{[\varphi_2;x;\mathrm{NP}]^2 \quad \dfrac{[\varphi_1;P;\mathrm{TV}]^1 \quad \mathsf{whiskas};\ \mathbf{w};\ \mathrm{NP}}{\varphi_1\circ\mathsf{whiskas};\ P(\mathbf{w});\ \mathrm{VP}}}{\varphi_2\circ\varphi_1\circ\mathsf{whiskas};\ P(\mathbf{w})(x);\ \mathrm{S}}}{\lambda\varphi_2.\varphi_2\circ\varphi_1\circ\mathsf{whiskas};\ \lambda x.P(\mathbf{w})(x);\ \mathrm{S}|\mathrm{NP}}}{\tau(\mathsf{dog})(\lambda\varphi_2.\varphi_2\circ\varphi_1\circ\mathsf{whiskas});\ \mathscr{F}(\mathbf{dog})(\lambda x.P(\mathbf{w})(x));\ \mathrm{S}}}{\lambda\tau.\tau(\mathsf{dog})(\lambda\varphi_2.\varphi_2\circ\varphi_1\circ\mathsf{whiskas});\ \lambda\mathscr{F}.\mathscr{F}(\mathbf{dog})(\lambda x.P(\mathbf{w})(x));\ \mathrm{S}|\mathrm{Det}}}{\lambda\varphi_1\lambda\tau.\tau(\mathsf{dog})(\lambda\varphi_2.\varphi_2\circ\varphi_1\circ\mathsf{whiskas});\ \lambda P\lambda\mathscr{F}.\mathscr{F}(\mathbf{dog})(\lambda x.P(\mathbf{w})(x));\ \mathrm{S}|\mathrm{Det}|\mathrm{TV}}$$

This is then conjoined with another expression of the same type via the determiner-gapping conjunction in (24) to yield the following coordinated S|Det|TV:

(26)

$$\dfrac{\begin{array}{l}\vdots\quad\vdots\\ \lambda\varphi_1\lambda\tau.\\ \tau(\mathsf{dog})(\lambda\varphi_2.\varphi_2\circ\varphi_1\circ\mathsf{whiskas});\\ \lambda P\lambda\mathscr{F}.\mathscr{F}(\mathbf{dog})(\lambda x.P(\mathbf{w})(x));\\ \mathrm{S|Det|TV}\end{array}\quad \dfrac{\begin{array}{l}\lambda\rho_2\lambda\rho_1\lambda\varphi\lambda\tau.\rho_1(\varphi)(\tau)\circ\\ \mathsf{or}\circ\rho_2(\varepsilon)(\varepsilon_{\mathsf{d}});\\ \sqcup;\mathbf{GC}(\mathrm{S|Det|TV})\end{array}\quad \begin{array}{l}\vdots\quad\vdots\\ \lambda\varphi_1\lambda\tau.\\ \tau(\mathsf{cat})(\lambda\varphi_2.\varphi_2\circ\varphi_1\circ\mathsf{alpo});\\ \lambda P\lambda\mathscr{F}.\mathscr{F}(\mathbf{cat})(\lambda x.P(\mathbf{a})(x));\\ \mathrm{S|Det|TV}\end{array}}{\begin{array}{l}\lambda\rho_1\lambda\varphi\lambda\tau.\rho_1(\varphi)(\tau)\circ\mathsf{or}\circ\mathsf{cat}\circ\mathsf{alpo};\\ \lambda\mathscr{W}.\mathscr{W}\sqcup\lambda P\lambda\mathscr{F}.\mathscr{F}(\mathbf{cat})(\lambda x.P(\mathbf{a})(x));\\ (\mathrm{S|TV|Det})|(\mathrm{S|TV|Det})\end{array}}}{\begin{array}{l}\lambda\varphi_1\lambda\tau.\tau(\mathsf{dog})(\lambda\varphi_2.\varphi_2\circ\varphi_1\circ\mathsf{whiskas})\circ\mathsf{or}\circ\mathsf{cat}\circ\mathsf{alpo};\\ \lambda P\lambda\mathscr{F}.\mathscr{F}(\mathbf{dog})(\lambda x.P(\mathbf{w})(x))\sqcup\lambda P\lambda\mathscr{F}.\mathscr{F}(\mathbf{cat})(\lambda x.P(\mathbf{a})(x));\mathrm{S|Det|TV}\end{array}}$$

Note in particular that the right string *cat alpo* is obtained for the second conjunct. This is a straightforward result of a couple of β-reduction steps:

(27) $$\begin{array}{l}\lambda\varphi\lambda\tau[\tau(\mathsf{cat})(\lambda\varphi'.\varphi'\circ\varphi\circ\mathsf{alpo})](\varepsilon)(\varepsilon_{\mathsf{d}}) = \lambda\varphi\lambda\sigma[\sigma(\varphi)](\mathsf{cat})(\lambda\varphi_2.\varphi_2\circ\varepsilon\circ\mathsf{alpo})\\ = \lambda\varphi_2[\varphi_2\circ\varepsilon\circ\mathsf{alpo}](\mathsf{cat}) = \mathsf{cat}\circ\varepsilon\circ\mathsf{alpo} = \mathsf{cat}\circ\mathsf{alpo}\end{array}$$

The rest of the derivation just involves combining the main verb and the negative determiner with this S|Det|TV expression.

(28)

$$\dfrac{\begin{array}{l}\lambda\rho.\rho(\lambda\varphi\lambda\sigma.\\ \sigma(\mathsf{no}\circ\varphi));\\ \lambda\mathscr{P}.\neg\mathscr{P}(\exists);\\ \mathrm{S|(S|Det)}\end{array}\quad \dfrac{\begin{array}{l}\mathsf{eats};\\ \mathbf{eat};\\ \mathrm{TV}\end{array}\quad \begin{array}{l}\vdots\quad\vdots\\ \lambda\varphi_1\lambda\tau.\tau(\mathsf{dog})(\lambda\varphi_2.\varphi_2\circ\varphi_1\circ\mathsf{whiskas})\circ\mathsf{or}\circ\mathsf{cat}\circ\mathsf{alpo};\\ \lambda P\lambda\mathscr{F}.\mathscr{F}(\mathbf{dog})(\lambda x.P(\mathbf{w})(x))\sqcup\\ \lambda P\lambda\mathscr{F}.\mathscr{F}(\mathbf{cat})(\lambda x.P(\mathbf{a})(x));\mathrm{S|Det|TV}\end{array}}{\begin{array}{l}\lambda\tau.\tau(\mathsf{dog})(\lambda\varphi_2.\varphi_2\circ\mathsf{eats}\circ\mathsf{whiskas})\circ\mathsf{or}\circ\mathsf{cat}\circ\mathsf{alpo};\\ \lambda\mathscr{F}.\mathscr{F}(\mathbf{dog})(\lambda x.\mathbf{eat}(\mathbf{w})(x))\sqcup\lambda\mathscr{F}.\mathscr{F}(\mathbf{cat})(\lambda x.\mathbf{eat}(\mathbf{a})(x));\mathrm{S|Det}\end{array}}}{\begin{array}{l}\mathsf{no}\circ\mathsf{dog}\circ\mathsf{eats}\circ\mathsf{whiskas}\circ\mathsf{or}\circ\mathsf{cat}\circ\mathsf{alpo};\\ \neg[\exists_{\mathbf{dog}}(\lambda x.\mathbf{eat}(\mathbf{w})(x))\vee\exists_{\mathbf{cat}}(\lambda x.\mathbf{eat}(\mathbf{a})(x))];\mathrm{S}\end{array}}$$

Crucially, just as in the analysis from the previous section, since the negative determiner scopes over the whole coordinated gapped sentence in this tectogrammatical derivation, the right semantic scope between the two operators is predicted. Thus, here again, the apparently anomalous scope relation between the negative quantifier and disjunction is a predicted consequence of the 'gapped' status of the former. The syntactic analysis of gapping requires the determiner to syntactically scope over the whole coordinate structure in the combinatoric structure, and the semantic scope between the two transparently reflects this underlying structural relationship.

3 Comparative subdeletion

We now turn to comparative subdeletion, illustrated in (29):

(29) John ate more donuts than Mary bought bagels.

This construction is similar to Gapping in that there is apparent deletion of some material in one of the two clauses involved: a determiner is missing in the *than* clause in a position where *more* appears in the main clause.

In the early literature of transformational grammar, there was a debate as to whether comparative subdeletion involves ellipsis or *wh*-movement. We here assume, following Hendriks (1995), that comparative subdeletion is in fact neither *wh*-movement nor deletion, but is rather to be analyzed along lines similar to the treatment of split gapping above. The primary motivation for this analysis comes from the fact that it yields the right compositional semantics immediately. To see this, note that what the comparative subdeletion sentence (29) compares is sizes of the sets $\{x : \mathbf{donut}(x) \wedge \mathbf{eat}(x)(\mathbf{j})\}$ and $\{x : \mathbf{bagel}(x) \wedge \mathbf{buy}(x)(\mathbf{m})\}$. Such sets can be obtained by abstracting over the determiner positions in the two clauses and supplying some appropriate operator $(\lambda P \lambda Q \lambda x[P(x) \wedge Q(x)])$ in that semantic argument position. On the prosodic side, *more-than* fills in an empty determiner phonology and the type-raised string *more* in the determiner-type gap positions of the two clauses and concatenates them with the string *than* in between. Thus, the lexical entry for *more-than* can be formulated as follows:

(30) $\lambda\rho_1\lambda\rho_2.\rho_2(\lambda\varphi\lambda\sigma.\sigma(\mathsf{more} \circ \varphi)) \circ \mathsf{than} \circ \rho_1(\varepsilon_{\mathsf{d}}); \textbf{more-than};$
$\mathrm{S}|(\mathrm{S}|\mathrm{Det})|(\mathrm{S}|\mathrm{Det})$

where the constant **more-than** stands for the following logical term:

(31) $\lambda\mathscr{F}\lambda\mathscr{G}.|\mathscr{G}(\lambda P\lambda Q\lambda x[P(x) \wedge Q(x)])| > |\mathscr{F}(\lambda P\lambda Q\lambda x[P(x) \wedge Q(x)])|$

Note here that since the determiner-type gap involves a higher-order prosodic variable in the present approach, the same identity element that fills in that gap in the second conjunct of determiner gapping is involved in 'closing off' the gap position of the *than* clause, and the phonology of *more* is identical in form to the type-raised determiner *no* from the previous section.

With this lexical entry for *more-than*, the derivation for (29) goes as follows:

(32)
$$\dfrac{\dfrac{\begin{array}{l}\lambda\rho_1\lambda\rho_2.\rho_2(\lambda\varphi\lambda\sigma.\\ \sigma(\mathsf{more}\circ\varphi))\circ\\ \mathsf{than}\circ\rho_1(\varepsilon_{\mathsf{d}});\\ \textbf{more-than};\\ \mathrm{S}|(\mathrm{S}|\mathrm{Det})|(\mathrm{S}|\mathrm{Det})\end{array} \quad \begin{array}{l}\vdots\quad\vdots\\ \lambda\tau.\tau(\mathsf{bagels})(\lambda\varphi.\mathsf{mary}\circ\mathsf{bought}\circ\varphi);\\ \lambda\mathscr{F}.\mathscr{F}(\mathbf{bagel})(\lambda x.\mathbf{buy}(x)(\mathbf{m}));\mathrm{S}|\mathrm{Det}\end{array}}{\begin{array}{l}\lambda\rho_2.\rho_2(\lambda\varphi\lambda\sigma.\sigma(\mathsf{more}\circ\varphi))\circ\mathsf{than}\circ\mathsf{mary}\circ\mathsf{bought}\circ\mathsf{bagels};\\ \textbf{more-than}(\lambda\mathscr{F}.\mathscr{F}(\mathbf{bagel})(\lambda x.\mathbf{buy}(x)(\mathbf{m})));\mathrm{S}|(\mathrm{S}|\mathrm{Det})\end{array}} \quad \begin{array}{l}\vdots\quad\vdots\\ \lambda\tau.\tau(\mathsf{donut})\\ (\lambda\varphi.\mathsf{john}\circ\mathsf{ate}\circ\varphi);\\ \lambda\mathscr{F}.\mathscr{F}(\mathbf{donut})\\ (\lambda x.\mathbf{eat}(x)(\mathbf{j}));\\ \mathrm{S}|\mathrm{Det}\end{array}}{\begin{array}{l}\mathsf{john}\circ\mathsf{ate}\circ\mathsf{more}\circ\mathsf{donuts}\circ\mathsf{than}\circ\mathsf{mary}\circ\mathsf{bought}\circ\mathsf{bagels};\\ \textbf{more-than}(\lambda\mathscr{F}.\mathscr{F}(\mathbf{bagel})(\lambda x.\mathbf{buy}(x)(\mathbf{m})))(\lambda\mathscr{F}.\mathscr{F}(\mathbf{donut})(\lambda x.\mathbf{eat}(x)(\mathbf{j})));\mathrm{S}\end{array}}$$

The final translation can be unpacked as:

(33) $|\{x : \mathbf{donut}(x) \wedge \mathbf{eat}(x)(\mathbf{j})\}| > |\{x : \mathbf{bagel}(x) \wedge \mathbf{buy}(x)(\mathbf{m})\}|$

We finish our discussion with a somewhat complex interaction between the two phenomena we have analyzed above, exemplified by (34):

(34) No dog eats more whiskas than Leslie buys pizza, or cat alpo.

This sentence has an interpretation which can be paraphrased as 'No dog eats more whiskas than Leslie buys pizza *and* no cat eats more alpo than Leslie buys pizza'. That is, it involves determiner gapping where, together with the determiner and the main verb, the discontinuous constituent *more . . . than Leslie* *buys pizza* (of syntactic type S|(S|Det)) is gapped from the second conjunct. The analysis is straightforward, the only complication being that this example involves abstracting over a yet higher-order type category (of type S|(S|Det)) for the discontinuous type-raised quantifier *more ... than Leslie buys pizza* in the two conjuncts. The identity element of this higher type to be fed to the second conjunct ($\varepsilon_{\mathsf{d}\uparrow} =_{def} \lambda\delta.\delta(\lambda\varphi\lambda\sigma.\sigma(\varphi))$) can be obtained by simply type-raising the determiner-type identity element ε_{d} over S. The derivation is given in (35).

(35)

$$\dfrac{\begin{array}{l}\quad\vdots\quad\vdots\\ \lambda\varphi_0\lambda\omega\lambda\rho_1.\omega(\lambda\rho_2.\\ \rho_2(\mathsf{whiskas})(\lambda\varphi_2.\rho_1(\mathsf{dog})\\ (\lambda\varphi_1.\varphi_1 \circ \varphi_0 \circ \varphi_2)));\\ \mathrm{S|Det|(S|(S|Det))|TV}\end{array} \qquad \dfrac{\begin{array}{l}\lambda\zeta_1\lambda\zeta_2\lambda\varphi\lambda\omega\lambda\rho.\\ \zeta_2(\varphi)(\omega)(\rho)\circ\\ \mathsf{or} \circ \zeta_1(\varepsilon)(\varepsilon_{\mathsf{d}\uparrow})(\varepsilon_{\mathsf{d}});\\ \mathbf{GC}\mathrm{(S|Det|(S|(S|Det))|TV)}\end{array} \quad \begin{array}{l}\quad\vdots\quad\vdots\\ \lambda\varphi_0\lambda\omega\lambda\rho_1.\omega(\lambda\rho_2.\\ \rho_2(\mathsf{alpo})(\lambda\varphi_2.\rho_1(\mathsf{cat})\\ (\lambda\varphi_1.\varphi_1 \circ \varphi_0 \circ \varphi_2)));\\ \mathrm{S|Det|(S|(S|Det))|TV}\end{array}}{\begin{array}{l}\lambda\zeta_2\lambda\varphi\lambda\omega\lambda\rho.\zeta_2(\varphi)(\omega)(\rho) \circ \mathsf{or} \circ \mathsf{cat} \circ \mathsf{alpo};\\ \mathrm{(S|Det|(S|(S|Det))|TV)|(S|Det|(S|(S|Det))|TV)}\end{array}}}{\begin{array}{l}\lambda\varphi\lambda\omega\lambda\rho.\omega(\lambda\rho_2.\rho_2(\mathsf{whiskas})(\lambda\varphi_2.\rho(\mathsf{dog})(\lambda\varphi_1.\varphi_1 \circ \varphi \circ \varphi_2))) \circ \mathsf{or} \circ \mathsf{cat} \circ \mathsf{alpo};\\ \mathrm{S|Det|(S|(S|Det))|TV}\end{array}}$$

$$\dfrac{\begin{array}{l}\lambda\rho.\rho(\lambda\varphi\lambda\sigma.\\ \sigma(\mathsf{no} \circ \varphi));\\ \mathrm{S|(S|Det)}\end{array} \qquad \dfrac{\begin{array}{l}\quad\vdots\quad\vdots\\ \lambda\rho_2.\rho_2(\lambda\varphi\lambda\sigma.\sigma(\mathsf{more} \circ \varphi))\circ\\ \mathsf{than} \circ \mathsf{leslie} \circ \mathsf{buys} \circ \mathsf{pizza};\\ \mathrm{S|(S|Det)}\end{array} \qquad \dfrac{\begin{array}{l}\mathsf{eats};\\ \mathbf{eat};\\ \mathrm{TV}\end{array} \quad \begin{array}{l}\quad\vdots\quad\vdots\\ \lambda\varphi\lambda\omega\lambda\rho.\omega(\lambda\rho_2.\rho_2(\mathsf{whiskas})\\ (\lambda\varphi_2.\rho(\mathsf{dog})(\lambda\varphi_1.\varphi_1 \circ \varphi \circ \varphi_2)))\circ\\ \mathsf{or} \circ \mathsf{cat} \circ \mathsf{alpo}; \mathrm{S|Det|(S|(S|Det))|TV}\end{array}}{\begin{array}{l}\lambda\omega\lambda\rho.\omega(\lambda\rho_2.\rho_2(\mathsf{whiskas})\\ (\lambda\varphi_2.\rho(\mathsf{dog})(\lambda\varphi_1.\varphi_1 \circ \mathsf{eats} \circ \varphi_2)))\circ\\ \mathsf{or} \circ \mathsf{cat} \circ \mathsf{alpo}; \mathrm{S|Det|(S|(S|Det))}\end{array}}}{\begin{array}{l}\lambda\tau_1.\tau_1(\mathsf{dog})(\lambda\varphi_1.\varphi_1 \circ \mathsf{eats} \circ \mathsf{more} \circ \mathsf{whiskas})\circ\\ \mathsf{than} \circ \mathsf{leslie} \circ \mathsf{buys} \circ \mathsf{pizza} \circ \mathsf{or} \circ \mathsf{cat} \circ \mathsf{alpo}; \mathrm{S|Det}\end{array}}}{\begin{array}{l}\mathsf{no} \circ \mathsf{dog} \circ \mathsf{eats} \circ \mathsf{more} \circ \mathsf{whiskas}\circ\\ \mathsf{than} \circ \mathsf{leslie} \circ \mathsf{buys} \circ \mathsf{pizza} \circ \mathsf{or} \circ \mathsf{cat} \circ \mathsf{alpo}; \mathrm{S}\end{array}}$$

4 Conclusion

Two related conclusions emerge from the above discussion. First, if we adopt the analysis of quantifier scope due to Oehrle (1994) in which quantificational determiners are treated as higher-order functors prosodically, then the empirical phenomena considered in this paper show that we need to recognize not just functors of higher-order prosodic types but also variables ranging over such higher-order functors. So far as we are aware, this is the first time that the need for such higher-order prosodic variables has been noted in the literature. This obviously raises the issue of how much complexity is needed in this domain, a question which we have to leave for another occasion.

Another, related point pertains to a comparison of the present proposal with related approaches to discontinuity. The most recent and well-developed framework for dealing with discontinuity within CG is the Displacement Calculus of Morrill et al. (2011) (which builds on the previous proposals by Morrill and Solias (1993); Morrill (1994), etc.). Though our Hybrid TLCG resembles Morrill et al.'s calculus in that both recognize directional slashes and non-directional syntactic connectives for dealing with discontinuity, there is one important difference between the two. In Hybrid TLCG, there is only one 'discontinuous' connective | (tied to lambda binding in phonology), whereas Morrill et al. recognize two counterparts of |, namely, ↑ and ↓, which respectively produce functors that wrap around their arguments and functors that are wrapped around by their arguments. With the distinction of these two syntactic connectives, certain aspects of the analysis can be simplified. Most notably, in the prosodic component, the only extension from the Lambek calculus is that 'separators' that keep track of gap positions are recognized as distinguished objects in the string algebra. Thus, in Morrill et al.'s calculus, no higher-order, functional entities are recognized in the prosodic component unlike in the Oehrle-style approach. Quantifiers and quantificational determiners are associated with strings, and their prosodic behaviors are encoded in the syntactic categories involving ↑ and ↓. Thus, in their approach, determiner gapping can simply be treated by abstracting over strings, without the complication of the higher-order treatment along lines we described above which is necessitated in the Oehrle-style treatment.

One might take this to be an advantage of the Morrill-style approach, but we believe that facts that bear on the comparison between the two types of approach come from more complex interactions between phenomena displaying discontinuity of the sort we sketched at the end of the previous section. The present approach, with a fully general lambda calculus in the prosodic component, straightforwardly extends to cases in which what is missing in a discontinuous constituent is itself a complex discontinuous constituent. By contrast, in the Morrill-style setup, there does not seem to be any straightforward way of treating the discontinuity exhibited by the gapped *more* + *than* S constituent in (34). Being of type S|(S|Det), this expression takes a determiner-gapped sentence and fills in the determiner *more* in the gap and concatenates the *than* clause to the resultant string. A lambda term for such a phonological functor is straightforward to write in the present approach, but in Morrill et al.'s setup, each functor is either a 'wrapper' or a 'wrappee', so a single expression cannot be both at the same time.[6] It thus seems reasonable to conclude that the present proposal offers the most general and empirically successful approach to discontinuity in the current CG literature.[7]

[6] There are of course ways around this problem, by mediating the interdependence between *more* and *than* via some syntactic mechanism (as indeed proposed by Morrill et al. (2011)). But such a solution seems to miss the point that the *more* + *than* clause in comparative subdeletion manifests discontinuous constituency.

[7] We acknowledge here that there remains an important theoretical issue: the formal properties of our hybrid implication logic are currently unknown. But note that in the domain of empirical science (including linguistics), empirical considerations should always take precedence over purely formal issues. In this connection, the point made by Boyer in his detailed history of calculus is, we think, particularly relevant:

> Perhaps the most manifest deterring force [for the development of calculus] was the rigid insistence on the exclusion from mathematics of any idea not at the time allowing of strict logical interpretation . . . it is clear that the indiscriminate use of methods and ideas which are without logical foundation is not

References

Barker, Chris. 2007. Parasitic scope. *Linguistics and Philosophy* 30:407–444.
Boyer, Carl. 1949. *The History of the Calculus and its Conceptual Development*. New York: Dover.
de Groote, Philippe. 2001. Towards abstract categorial grammars. In *Proceedings of ACL 39*, 148–155.
Hendriks, Petra. 1995. Ellipsis and multimodal categorial type logic. In G. V. Morrill and R. T. Oehrle, eds., *Proceedings of Formal Grammar 1995*, 107–122.
Jacobs, Joachim. 1980. Lexical decomposition in Montague grammar. *Theoretical Linguistics* 7(1/2):121–136.
Johnson, Kyle. 2000. Few dogs eat Whiskers or cats Alpo. In K. Kusumoto and E. Villalta, eds., *UMOP 23*, 47–60. Amherst, MA: GLSA.
Kubota, Yusuke and Robert Levine. 2012. Gapping as like-category coordination. In D. Béchet and A. Dikovsky, eds., *LACL 2012 Proceedings*, 135–150. Springer.
Kubota, Yusuke and Robert Levine. 2013. Against ellipsis: Arguments for the direct licensing of 'non-canonical' coordinations. MS., OSU.
Kuno, Susumu. 1976. Gapping: A functional analysis. *Linguistic Inquiry* 7:300–318.
Lambek, Joachim. 1958. The mathematics of sentence structure. *American Mathematical Monthly* 65:154–170.
McCawley, James D. 1993. Gapping with shared operators. In D. A. Peterson, ed., *Berkeley Linguistics Society*, 245–253. University of California, Berkeley, California.
Montague, Richard. 1973. The proper treatment of quantification in ordinary English. In J. Hintikka, J. M. Moravcsik, and P. Suppes, eds., *Approaches to Natural Language*, 221–242. Dordrecht, Holland: D. Reidel.
Morrill, Glyn. 1994. *Type Logical Grammar*. Dordrecht: Kluwer.
Morrill, Glyn and Teresa Solias. 1993. Tuples, discontinuity, and gapping in categorial grammar. In *Proceedings of EACL 6*, 287–296. Morristown, NJ, USA: ACL.
Morrill, Glyn, Oriol Valentín, and Mario Fadda. 2011. The displacement calculus. *Journal of Logic, Language and Information* 20:1–48.
Muskens, Reinhard. 2003. Language, lambdas, and logic. In G.-J. Kruijff and R. Oehrle, eds., *Resource Sensitivity in Binding and Anaphora*, 23–54. Kluwer.
Oehrle, Richard T. 1987. Boolean properties in the analysis of gapping. In G. J. Huck and A. E. Ojeda, eds., *Discontinuous Constituency*, 203–240. Academic Press.
Oehrle, Richard T. 1994. Term-labeled categorial type systems. *Linguistics and Philosophy* 17(6):633–678.
Penka, Doris. 2011. *Negative Indefinites*. Oxford: Oxford University Press.
Pollard, Carl. 2011. Proof theoretic background for Linear Grammar. MS., OSU.
Pollard, Carl and E. Allyn Smith. 2012. A unified analysis of *the same*, phrasal comparatives and superlatives. In *Proceedings of SALT 2012*, 307–325.
Siegel, Muffy E. A. 1984. Gapping and interpretation. *Linguistic Inquiry* 15:523–530.

> to be condoned . . . but pending the final establishment of this, the banishment of suggestive views is a serious mistake. (Boyer, 1949, 301–302)

Our system, so far as we can tell, makes systematic predictions which correspond to the empirically observed patterns exactly, and hence seems to achieve a level of 'suggestiveness' which entitles it to further investigation of its logical foundations.