PREDICATES *AND* FORMULAS: EVIDENCE FROM ELLIPSIS*

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Abstract

This paper discusses a pattern of argument identity effects in antecedent-contained VP-deletion, first discussed in Kennedy 1994, that cannot be explained under standard assumptions about the interpretation of such constructions. In developing an account of these facts, I will make crucial use of a syntax and semantics for quantification in which the expression that introduces the restriction term of a quantifier denotes a predicate, but the one that introdues the scope term denotes an open proposition, and binders denote second-order properties of assignment functions (Sternefeld 1998, 2001, Kobele 2006, 2010). This approach differs from the standard syntax and semantics for quantification, in which both restriction and scope terms denote predicates, but it shares important features with the analysis of quantification and variable binding proposed by Irene Heim in her own (Heim 1997) account of the same pattern of data.

1 Argument identity in ACD

Kennedy (1994) observes contrasts between typical examples of antecedent-contained VP-deletion (ACD) like (1a) and (2a), in which the internal arguments of the antecedent and elided VPs are understood as "the same" (in a sense to be made more precise shortly), and examples like (1b) and (2b), in which they are not.

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(1) a. Polly visited every major city Erik did ~~[$_{VP}$ visit]~~.
b. * Polly visited every major city that is located in a state that Erik did ~~[$_{VP}$ visit]~~.

(2) a. David contacted most of the senators that Michelle did ~~[$_{VP}$ contact]~~.
b. * David contacted most of the senators who have aides that Michelle did ~~[$_{VP}$ contact]~~.

(1)-(2) involve ACD in direct objects, but the contrast is systematic, showing up as well with indirect objects (3) and embedded or small clause subjects (4)-(5).

(3) a. David sent a letter to every senator Michelle did ~~[$_{VP}$ send a letter to]~~.
b. * Erik sent a letter to every aide who worked for a senator Michelle did ~~[$_{VP}$ send a letter to]~~.

(4) a. Edith wants the candidates that Jack does ~~[$_{VP}$ want to be successful]~~ to be successful.
b. * Edith wants the rivals of the candidates that Jack does ~~[$_{VP}$ want to be successful]~~ to be successful.

(5) a. Polly considers every senator Erik does ~~[$_{VP}$ consider corrupt]~~ corrupt.
b. * Polly considers every aide who works for a senator Eric does ~~[$_{VP}$ consider corrupt]~~ corrupt.

Importantly, this contrast is about *ellipsis:* variants of the (b) sentences in the preceding examples in which the elided VPs are pronounced are all perfectly acceptable, even if the redundant VPs are deaccented. At first glance, then, the fact that a position contained inside an elided VP needs to be understood in the same way as a corresponding position in its antecedent VP does not look particularly surprising, given that ellipsis is licensed by an identity condition of some sort or another (see van Craenenbroeck and Merchant 2013 for a recent survey of approaches). Such a condition ensures, for example, that (6) can only be understood as in (6a), not as in (6b).

(6) Polly is really interested in Chicago, but her travel plans depend on Erik. If Erik visits Illinois, she will.
a. ~~[$_{VP}$ visit Illinois]~~
b. * ~~[$_{VP}$ visit Chicago]~~

Extending this line of thought to the contrasts in (1)-(5), we could hypothesize that ellipsis is impossible in (1b), for example, because it says that Polly is visiting cities and that Erik is visiting states. In contrast, ellipsis is acceptable in (1a) because here we are saying that both Polly and Erik are visiting cities, and more precisely, that every major city that Erik visits is also such that Polly visits *it*.

At first glance, the "standard analysis" of ACD appears to lead directly to this intuitive account of the contrasts in (1)-(5). According to this analysis, the reason that ACD is possible in the first place — i.e., the reason that the syntactic configuration that superficially characterizes ACD constructions does not give rise to an infinite regress, whereby an elided VP is required to be (syntactically or semantically) identical to a constituent that contains it — is because the content of the constituent that contains the elided VP is effectively "pulled out" of the content of the antecedent VP at whatever level of representation is relevant for licensing ellipsis (see Sag 1976, May 1977, 1985 and much subsequent work). According to the standard analysis, the (a) sentences all have the logical structure shown schematically in (7a), with the particular case of (1a) shown in (7b). VP_e and VP_a represent the contents of the elided and antecedent VPs, respectively.

(7) a. For Q x such that ... [$_{\mathrm{VP}e}$ ... x ...], ... [$_{\mathrm{VP}a}$ ... x ...]
b. For every x such that x is a major city and Erik [$_{\mathrm{VP}e}$ visited x], Polly [$_{\mathrm{VP}a}$ visited x]

Here the relevant positions inside the elided and antecedent VPs (indicated by the variable x) are assigned the same semantic values, and ellipsis is possible.

In contrast, the (b) sentences all have the logical structure shown schematically in (8a), with (8b) showing the structure of (1b).

(8) a. For Q x such that ... for R y such that ... [$_{\mathrm{VP}e}$ ... y ...], ... [$_{\mathrm{VP}a}$ ... x ...]
b. For every x such that x is a major city and for some y such that y is a state and x is in y and Erik [$_{\mathrm{VP}e}$ visited y], Polly [$_{\mathrm{VP}a}$ visited x]

Here the semantic values of the relevant positions inside the elided and antecedent VPs are not guaranteed to be the same: the value of x in the antecedent VP is determined in virtue of its relation to Q (*every* in (8b)), and the value of y in the elided VP is determined in virtue of its relation to R (*some* in (8b)). If ellipsis requires identity, and if identity is not guaranteed here, then we would seem to correctly predict ellipsis to be impossible.

The problem with this intuitive account of the data, however, is that there are other configurations in which ellipsis is acceptable even though parallel positions inside the elided and antecedent VPs are valued differently. For example, in (9a-b), the values of the direct object positions inside the antecedent and elided VPs are valued in relation to the preposed *wh*-phrases and topicialized DPs, respectively (Evans 1988).

(9) a. Polly told us which cities she visited, and Erik told us which states he did ~~[$_{\mathrm{VP}}$ visit]~~.
b. Chicago, she's visited. St. Louis, she hasn't ~~[$_{\mathrm{VP}}$ visited]~~.

(10a-b) make the same point in an even more striking way: these examples are quasi-paraphrases of (1b) and (2b), in which the things visited and individuals contacted are distinct in the antecedent and elided VPs, and yet ellipsis is perfectly acceptable (Jacobson 1998).

(10) a. Every major city that Polly visited is located in a state that Erik did ~~[$_{\mathrm{VP}}$ visit]~~.
b. Most of the senators that David contacted have aides that Michelle did ~~[$_{\mathrm{VP}}$ contact]~~.

What these facts show is that the contrasts in (1)-(5) are not just about ellipsis, they are also about *configuration.* The descriptive generalization that characterizes the pattern is stated in (11).[1]

[1] This is a modified version of a similar generalization in Kennedy 1994, which was broader because it was designed to also cover cases in which one of VP_e or VP_a is contained in the subject of the other, such as (ia-b) (cf. Wasow 1972).

(i) a. The girl who wanted to win did ~~[$_{\mathrm{VP}}$ win]~~.
b. ?? The girl who wanted her best friend to win did ~~[$_{\mathrm{VP}}$ win]~~.

I now believe that the contrast in (i) should be explained differently from the contrasts in (1)-(5). While the contrasts in (1)-(5) are quite robust across examples and speakers, the one in (i) is a lot more variable, with more speakers willing to accept (ib). Moreover, as already pointed out in Kennedy 1994, (ib) improves drastically by adding *instead* or *too* (as appropriate for the particular example), while no such improvement is found with the ACD examples. See Hardt and Asher 1997 for an account of the contrast in (i) (but not of (1)-(5)) based on the discourse dynamics of ellipsis.

(11) Ellipsis between VP_e and VP_a, VP_e contained in an expression that saturates an argument position inside VP_a, is licensed only if the semantic value assigned to the argument position saturated by C in VP_a is identical to the semantic value assigned to the corresponding argument position in VP_e.

My goal in this paper is to account for this generalization, and in so doing to argue for an approach to the syntax and semantics of quantifier/variable binding configurations in which the syntactic scope of a binder is an open proposition (or a function from assignment functions to truth values), and a binder denotes a second-order property of assignment functions (Sternefeld 1998, 2001, Kobele 2006, 2010; see also Chierchia and McConnell-Ginet 1990, Sternefeld and Zimmermann 2013). This approach differs from the most prominent analysis of quantifier/variable binding configurations on the market today — Heim and Kratzer's (1998) rule of Predicate Abstraction — which does not support an account of the ellipsis data presented here. However, it shares important features with the analysis of quantifier/variable binding proposed by Irene Heim in her own analysis of the ellipsis facts we have just examined (Heim 1997), so it is with a discussion of her proposals that I will begin.

2 Predicates or formulas?

Heim's analysis consists of three parts, all of which are crucial. The starting point is the theory of ellipsis licensing articulated in Rooth 1992, which has the following components:

(12) a. A deleted VP and its antecedent must have the same lexical material up to indexical values on traces, pronouns, etc.
b. A deleted VP must be contained in a constituent that contrasts appropriately with some constituent that contains the antecedent VP.

The notion of "appropriate contrast" appealed to here is the same one that is relevant for the licensing of focus/deaccenting in Rooth's theory of focus (Rooth 1985):

(13) A constituent ϕ contrasts appropriately with a constituent ψ iff:
a. ϕ and ψ don't overlap, and
b. for all assignments g, the regular semantic value of ψ with respect to g is an element of the focus value of ϕ with respect to g.

To see how Rooth's analysis works, consider first (14).

(14) I know what$_1$ Polly [$_{VP}$ saw t_1] but not what$_2$ Erik did ~~[$_{VP}$ see t_2]~~

Ellipsis is licensed in (14) even though the elided and antecedent VPs differ in the indices on the VP-internal traces because: 1) the identity condition in (12a) allows for such indexical variation, and (crucially) 2) the elided VP is contained in a constituent that satisfies the appropriate contrast condition in (12b), namely the embedded question in the second conjunct. Here the DP *Erik* is in focus, so the focus semantic value of this constituent is the set of questions that we get by replacing the meaning of *Erik* with the meaning of other DPs, including *Polly*. The embedded questions in the first and second conjuncts do not overlap, and since all of the variables in these constituents are bound, the regular semantic value of the former is a member of the focus value of the latter, and ellipsis is licensed.

In contrast, this theory forbids ellipsis in the very similar LF in (15).

(15) * I know whether Polly [$_{\text{VP}}$ saw him$_1$] but not whether Erik did ~~[$_{\text{VP}}$ see *him*$_2$]~~

Although the identity condition in (12a) allows for variation in the indexical values on the pronouns here, the appropriate contrast condition fails: *him*$_1$ and *him*$_2$ are unbound, so (as long as there are multiple relevant individuals in the domain) there are some assignments in which the pronouns get different values, in violation of (13b). The result is that the theory correctly predicts that (15) cannot be used to convey the information that I know whether Polly saw Paul but not whether Erik saw Pat, even if I point at Paul when I utter *"Polly saw him"* and point at Pat when I utter *"Erik did."*

Rooth's theory of ellipsis is quite general, and has been fruitfully exploited by many authors to account for various patterns of interpretation in ellipsis structures (see e.g., Jacobson 1998, Romero 1998, Fox 1999b, Tomioka 1999, Sauerland 2004); and I will also assume it in the analysis I will propose in the next section.[2] The other two components of Heim's analysis, however, are introduced specifically to account for the generalization in (11). The first is a general constraint on variable names that Heim labels NO MEANINGLESS COINDEXING, which is stated in (16).

(16) If a LF contains an occurrence of a variable v that is bound by a node α, then all occurrences of v in this LF must be bound by the same node α.

This constraint rules out "semantically inert" coindexation in a Logical Form like (17), requiring instead the use of something like (14) (or any other LF in which the relevant indices are distinct) to convey the same information.

(17) * I know what$_1$ Polly saw t_1 but not what$_1$ Erik did ~~[$_{\text{VP}}$ see t_1]~~

The final component of Heim's analysis is the hypothesis that the constituents that provide the restriction and scope terms of a quantificational determiner denote open propositions, as originally proposed by Montague (1974) (see also Heim 1982, Kamp 1981, Kamp and Reyle 1993 and much subsequent work in dynamic semantics). On this view, which Heim calls the FORMULAS HYPOTHESIS, the interpretation of e.g. a quantificational structure involving *every* is as shown in (18).[3]

(18) $$\left[\!\left[\, [[\text{every}_i\ \rho]\ \sigma] \,\right]\!\right]^g = 1 \text{ iff for every } x \text{ such that } [[\rho]]^{g[x/i]} = 1,\ [[\sigma]]^{g[x/i]} = 1$$

[2]See Merchant 2001 for a related approach to ellipsis licensing. For my purposes, the main difference between Merchant's analysis and Rooth's analysis is that variable-denoting expressions bound from outside the VP play a more significant role in (anti-)licensing ellipsis in the latter than in the former, something that will be crucial to the accounts of the contrasts in (1)-(5) that I will consider in this paper. On the other hand, Merchant's licensing condition is fully semantic, lacking the syntactic identity condition in (12a). In Section 4.2, I will present data from Jacobson 1998 that supports the position in Merchant 2001 that the licensing condition is fully semantic. This will lead to a modification of Rooth's analysis (the core of which I maintain for the reasons mentioned above) along the lines suggested in Fox 1999a and Sauerland 2004.

[3]Note that this part of Heim's analysis is strictly a proposal about the syntax-semantics interface; it is not a proposal about the kind of meanings that quantificational determiners have. We could just as well characterize the meaning of *every* in terms of a relation between sets as in (i).

Below I will return to a comparison of the Formulas Hypothesis with the more standard PREDICATES HYPOTHESIS, in which the restriction and scope terms denote of individuals properties (as in Heim and Kratzer 1998 as well as most work taking a directly compositional approach to quantification; see e.g. Jacobson 1992, 1998, 1999). First, though, let us see how the different parts of Heim's analysis interact to derive the generalization in (11) and the pattern of acceptability discussed in Section 1.

Consider the acceptable and unacceptable examples of ACD in (19a) and (20a), and hypothetical LFs in (19b) and (20b). To keep the representations as clear as possible, I indicate only the semantically relevant portions, leaving out relative operators (which play no role in the Formulas Hypothesis) and also leaving out the variables introduced by the nominal heads. With Heim, I adopt a standard "QR analysis" of quantificational DPs in internal argument positions, though to keep things simple, I will not indicate QR in the representations when it is not important.

(19) a. Polly visited every major city that Erik did.
b. [every$_1$ major city Erik did ~~[$_{\text{VP}}$ visit t_1]~~] [Polly PAST [$_{\text{VP}}$ visit t_1]]

(20) a. * Polly visited every major city that is located in a state that Erik did.
b. [every$_1$ major city [t_1 located in a$_2$ state Erik did ~~[$_{\text{VP}}$ visit t_2]~~]]
[Polly PAST [$_{\text{VP}}$ visit t_1]]

In both (19b) and (20b), the syntactic identity requirement on deletion is met, because the antecedent and elided VPs differ at most in the indices assigned to traces. In (19b), the appropriate contrast condition can also be met simply by comparing the elided and antecedent VPs. The focus value of the elided VP for any g is the singleton set containing the property $\lambda x.\mathbf{visit}(g(1))(x)$ (since nothing is in focus), which is the same as the regular semantic value of the antecedent VP for any g, thus the elided VP contrasts appropriately with the antecedent VP. Note that this particular way of satisfying the contrast condition is an option precisely because the traces inside the two VPs are (and, as we will see, must be) coindexed, and such coindexation is compatible with No Meaningless Coindexation because both traces are bound by the same expression: the determiner *every$_1$*.

In (20b), however, there is no way to satisfy the appropriate contrast condition. (21) lists the set of constituents that contain the elided VP.

(21) a. ~~[$_{\text{VP}}$ visit t_2]~~
b. did ~~[$_{\text{VP}}$ visit t_2]~~
c. Erik did ~~[$_{\text{VP}}$ visit t_2]~~

(i) $\left[\!\left[\ [\,[\text{every}_i\ \rho]\ \sigma\,]\ \right]\!\right]^g = 1$ iff $\{x \mid [[\rho]]^{g[x/i]} = 1\} \subseteq \{x \mid [[\sigma]]^{g[x/i]} = 1\}$

Also, as pointed out by Heim, it is possible to give a non-syncategorematic version of this analysis by analyzing all expressions as functions from assignment functions to their "normal" types (cf. Rooth 1985, Kobele 2010). In the case of (18), for example, this would give us (ii), where a is the type of assignment functions.

(ii) $[[every_i]]^g = \lambda p_{\langle a,t\rangle}\lambda q_{\langle a,t\rangle}$for every x such that $p(g[x/i]) = 1$, $q(g[x/i]) = 1$

I will end up arguing for a variant of this kind of approach in Section 3.

d. [a_2 state Erik did ~~[$_{VP}$ visit t_2]~~]

e. [$every_1$ major city [[t_1 located in a_2 state Erik did ~~[$_{VP}$ visit t_2]~~]]

In order to license ellipsis, it must be the case that the focus value of at least one of (21a-e) includes the regular semantic value of a non-overlapping constituent that contains the antecedent VP. There are only three options to consider here, shown in (22a-c): the antecedent VP itself, the minimal constituent containing tense, and the minimal constituent containing the matrix subject. Anything larger would violate the no-overlap condition.

(22) a. [$_{VP}$ visit t_1]

b. PAST [$_{VP}$ visit t_1]

c. Polly PAST [$_{VP}$ visit t_1]

Clearly, none of (22a-c) are elements of the focus values of (21d-e), since the latter are based on DP meanings and the former are properties and propositions. But even though (22a-c) and (21a-c) are isomorphic, and even if we are lenient in our assumptions about where focus is assigned, none of the former are members of the focus values of any of the latter, for all assignments of values to variables, because the VP-internal traces bear distinct indices, in accord with No Meaningless Coindexing.

In this particular example No Meaningless Coindexing does not actually have to be stipulated: if the VP-internal traces were coindexed, and therefore the two determiners were coindexed, we would derive a structure in which *a* binds all the variables inside the complex DP:

(23) [$every_1$ major city [a_1 state Erik did ~~[$_{VP}$ visit t_1]~~] [t_1 located in t_1]]
[Polly PAST [$_{VP}$ visit t_1]]

Regardless of whether a structure like (23) is interpretable, it does not convey the meaning we are trying to convey with (20a) (in which the cities are located in the states), and so is not a plausible LF for this example. But, as pointed out by Jacobson (1998), No Meaningless Coindexing is crucial for examples that involve additional embedding, such as (24a).

(24) a. * Polly visited every city that was recommended in a guidebook that also recommended the city that Erik did ~~[$_{VP}$ visit]~~

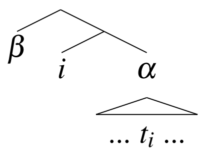
b. [$every_1$ city that t_1 was recommended in a_2 guidebook that t_2 also recommended [the_1 city Erik did ~~[$_{VP}$ visit t_1]~~]] [Polly PAST [$_{VP}$ visit t_1]]

(24b) is fully interpretable, and has the meaning we want, and would license ellipsis because the elided VP contrasts appropriately with the antecedent VP, thanks to coindexation on the VP-internal traces (as in (19)). Thus No Meaningless Coindexation is a crucial part of the analysis.

Likewise, the Formulas Hypothesis, in which the restriction and scope of a quantificational determiner denote open propositions, is a crucial part of Heim's analysis. This can be seen by comparing it to the Predicates Hypothesis, in which the restriction and scope of a quantificational determiner denote functions from individuals to truth values, as in (25).

(25) $[\![\, [\,[\text{every}\ \rho]\ \sigma\,]\,]\!]^g = 1$ iff for every x such that $[\![\rho]\!]^g(x) = 1$, $[\![\sigma]\!]^g(x) = 1$

The Predicates Hypothesis is worked out in great detail in the compositional framework developed in Heim and Kratzer 1998, in which the restriction and scope terms denote functions of type $\langle e,t\rangle$ either in virtue of their "basic" meanings (when, e.g., ρ is NP and σ is VP), or in virtue of Heim and Kratzer's analysis of the syntax and semantics of scope-taking. On the syntactic side, Heim and Kratzer propose that scope-taking involves movement of a quantificational expression to its scope position, and that movement in general of β to α generates structures of the form in (26), where i is an index and t_i is a trace in the original position of β.

(26) 

On the semantic side, Heim and Kratzer propose that the "index adjunction" structures created by movement are interpreted by the rule of PREDICATE ABSTRACTION in (27).

(27) For any index i, constituent α, and assignment function g, $[\![\,[\, i \;\; \alpha \,]\,]\!]^g = \lambda z.[[\alpha]]^{g[z/i]}$

In a typical example of ACD like (28a), the Predicates Hypothesis assigns a Logical Form along the lines of (28b).

(28) a. Polly visited every major city that Erik did.

b. [every major city [*wh* 1 [Erik did ~~[$_{\text{VP}}$ visit t_1]~~]]] [2 [Polly PAST [$_{\text{VP}}$ visit t_2]]]

Here the VP-internal traces in the elided and antecedent VPs are bound by distinct operators (the relative *wh*-operator and raised QP, respectively; the former is semantically vacuous), so I have assigned them distinct indices in accord with No Meaningless Coindexing. But this causes no problem for ellipsis licensing: assuming focus on *Erik*, the focus value of the index-adjunction structure in the relative clause is the set of functions from individuals to truth values shown in (29a), and the regular semantic value of the index adjunction structure that provides the scope term for *every* is the function from individuals to truth values in (29b). The latter is an element of the former, so the contrast condition is satisfied.

(29) a. $\{\lambda x.\mathbf{visit}(x)(y) \mid y \text{ an alternative for } \mathbf{erik}\}$

b. $\lambda x.\mathbf{visit}(x)(\mathbf{polly})$

Crucially, even though the corresponding variables in the antecedent and elided VPs are distinct, they are both bound within the constituents that are compared for the focus condition, so their semantic values do not change across assignment functions. The result is that the elided VP is contained in constituent that contrasts appropriately with a non-overlapping constituent containing the antecedent VP, and ellipsis is correctly licensed.[4]

The problem is that in the Heim and Kratzer version of the Predicates Hypothesis, it is a simple matter to generate a Logical Form for ungrammatical examples like (30a) that also licenses ellipsis. (30b) is one of them.

[4]The acceptability of ellipsis in the examples in (9) and (10), discussed in Section 1, is accounted for in the same way. Even though the antecedent and elided VPs contain distinct variables bound by distinct binders, the contrast condition can be satisfied because for larger constituents containing these VPs in which the variables are bound.

(30) a. * Polly visited every major city that is located in a state that Erik did.

b. [every major city [1 [t_1 located in a state [2 [Erik did ~~[$_{\mathrm{VP}}$ visit t_2]~~]]]]]
[3 [Polly PAST [$_{\mathrm{VP}}$ visit t_3]]]

Here the index-2 adjunction structure, which provides part of the restriction of *a*, contains the elided VP and contrasts appropriately with the index-3 adjunction structure, which provides the scope of *every* and contains the antecedent VP. The problem, in a nutshell, is that a consequence of the Predicates Hypothesis is that the VP-internal traces are bound inside non-overlapping constituents, which in effect makes their indexical values irrelevant to the calculation of the contrast condition on ellipsis: unacceptable examples like (30a) satisfy this condition in exactly the same way as acceptable examples like (28a). In contrast, the Formulas Hypothesis entails that the VP-internal traces are free inside all relevant non-overlapping constituents; this, together with No Meaningless Coindexing, allows us to correctly distinguish between these two kinds of examples and derives the generalization in (11).

Heim's analysis provides a quite general and comprehensive account of the facts discussed in Section 1. However, it faces both theoretical and empirical challenges. On the theoretical side, the main questions involve the very same principles that make the analysis work: the Formulas Hypothesis and the No Meaningless Coindexing constraint. The former involves a move away from the current standard thinking about the semantics of nominals and modifiers (though not one without a significant precedent in the work of Montague and dynamic semantics), and the latter is a stipulation that doesn't follow from any independent property of the syntax or semantics of variable binding.

The most serious challenge to Heim's analysis comes from the empirical side, however: as observed by Jacobson (1998), the analysis makes the wrong predictions about examples like (10a), repeated below as (31a).

(31) a. Every major city that Polly visited is located in a state that Erik did.

b. [every$_1$ major city that Polly PAST [$_{\mathrm{VP}}$ visit t_1]] is located in
[a$_2$ state that Erik did ~~[$_{\mathrm{VP}}$ visit t_2]~~]

The problem here is that No Meaningless Coindexing requires the VP-internal traces to bear distinct indices, as shown in (31b). This is not a problem for the syntactic identity condition on ellipsis (which allows indexical variation), but it is a problem for the contrast condition, because the Formulas Hypothesis ensures that these expressions are free in any constituents that are potential (i.e., non-overlapping) candidates for satisfying this condition. The result is that (31a) is incorrectly predicted to be unacceptable for the same reason as the examples in Section 1, and we must conclude with Jacobson (1998) that Heim's analysis as it stands cannot be maintained.[5] In the next section I will propose an alternative.

[5] Jacobson presents a variable free analysis of ACD which easily handles examples like (31a), but which cannot explain the ACD pattern discussed in Section 1, essentially for the same reason that the Predicates Hypothesis fails: the restriction and scope arguments of a quantifier are interpreted directly using function composition, and no instance of composition involves constituents with assignment-dependent meanings. Jacobson's analysis does, however, correctly account for a different set of examples involving pied-piping that are similar in certain respects to the ACD data discussed in Section 1, which I will discuss in Section 4.2. Jacobson (2008) presents an updated version of her analysis which, she argues, can account for the identity effects in the core cases, but unfortunately I will not have space here to do a proper comparison of my proposals with hers.

3 Predicates *and* formulas

My analysis starts from the assumption that Heim's core hypothesis about the generalization in (11) and the pattern of data in Section 1 is correct: ellipsis is impossible in the unacceptable examples because the particular syntactic configuration that characterizes these cases is such that the contrast condition on ellipsis can be satisfied only when the relevant VP-internal variables are the same. I will depart from Heim in two ways, aiming first to resolve the empirical challenge presented by examples like Jacobson's (31), and second to discharge the theoretical concerns about the Formulas Hypothesis and the No Meaningless Coindexing Constraint.

Let us begin by taking another look at (31). As Jacobson points out, this kind of example is easily handled in analyses that use the Predicates Hypothesis to compute the meaning of relative clauses: we need only examine the two relative clauses shown in (32a-b) to see that this is the case.

(32) a. [every major city [1[that Polly PAST [$_{\text{VP}}$ visit t_1]]]]
b. [a state [2[that Erik did ~~[$_{\text{VP}}$ visit t_2]~~]]]

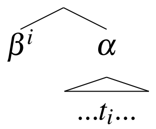
Here ellipsis is licensed because the two VPs are identical up to indices on traces, and assuming focus on the DP *Erik*, the relative clause containing the elided VP contrasts appropriately with the relative clause containing the antecedent VP. Crucially, even though the VP-internal traces introduce distinct variables, they are bound within the compared constituents, so there is no variation in meaning across different assignment functions.

This kind of example appears to provide fairly strong evidence that the Predicates Hypothesis is correct for relative clauses. But must it also be correct for the expression that provides the scope of a quantificational determiner? This is the assumption that underlies the syntax and semantics of scope-taking and movement in Heim and Kratzer 1998, encapsulated in the formulation of the Predicate Abstraction rule in (27), but as we saw in the previous section, this gives us the wrong results for the full pattern of ACD data introduced in Section 1. I would therefore like to propose an alternative syntax and semantics for scope-taking in which quantifier restriction expressions denote predicates, but quantifier scope expressions denote formulas: the PREDICATES AND FORMULAS HYPOTHESIS.

At first, this proposal may sound a bit *ad hoc*, and in fact Sauerland (2004, pp. 83-34) briefly considers a variant of this idea and rejects it as unworkable.[6] However, I believe that it can be made to follow form a couple of rather simple, and arguably quite theoretically satisfying assumptions, almost all of which have already been proposed in previous literature and worked out in most detail by Sternefeld (1998, 2001) and Kobele (2006, 2010). (The core idea can also be seen in Chierchia and McConnell-Ginet's (1990) interpretation rule for quantification constructions, though they do not consider relative clauses.) The first involves the syntax and semantics of scope-taking/variable-binding, which I assume involves the configuration in (33), where β^i is the scope-taking/binder and α is its scope.[7]

[6]Sauerland actually considers a version in which the restriction term denotes a formula and the scope term denotes a predicate. Such an analysis may, indeed, be unworkable; certainly it cannot be implemented in as straightforward and simple a fashion as the analysis that I will present here, in which the restriction term is a predicate and the scope term is a formula.

[7]For now, I will continue to assume that this configuration is derived by movement, but that is not crucial: the analysis could be reformulated in a directly compositional approach to binding/scope-taking with a quantifying-in rule (see Kubota in press for a particularly nice implementation), particularly if we adopt the suggestion below

(33)


In essence, this is just the traditional view in which indices are features of syntactic expressions, rather than objects with their own independent syntactic status whose role in the semantics is to trigger a syncategorematic interpretation rule, as in Heim and Kratzer 1998. The superscript vs. subscript notation in (33) indicates the role that an index plays in the interpretation of variables vs. binders (cf. Heim 1993). A subscript index is a feature on the expressions of the language that have interpretations as variables; for the purposes of this paper, I will only concern myself with those variable-denoting expressions that enter the representation in virtue of their role in the syntax of movement, i.e. traces/copies, and I will assume the standard interpretation rule in (34).[8]

(34) $[[t_i]]^g = g(i)$

The superscript index, on the other hand, is a feature on the head of the moved expression whose function is to indicate which position(s) inside the expression's syntactic scope it binds. There are a number of different options for operationalizing this idea, which bear on the formulation of the rule for interpreting the structure in (33). One option is, in effect, to build Predicate Abstraction directly into a composition rule for interpreting structures like (33), as in (35) (cf. Reinhart 1983a,b, Cook and Glanzberg 2013).

(35) If $[[\beta]]^g$ is type $\langle\langle e,t\rangle,t\rangle$ and $[[\alpha]]^g$ is type t, then $[[\beta^i\ \alpha]]^g = [[\beta]]^g(\lambda z.[[\alpha]]^{g[z/i]})$

This option assumes a standard type $\langle\langle e,t\rangle,t\rangle$ type for generalized quantifiers (including lifted expressions of type e), and like Heim and Kratzer's Predicate Abstraction rule, it basically involves a syncategorematic treatment of the binding index. But crucially for the account of the ellipsis data, all variables inside α that end up bound by β in virtue of (35), are free inside α: there is no constituent other than $[\alpha\beta]$ in which these variables are bound.

The second and more general option is to provide a semantics for superscript indexing that "does the right thing," as in the work of Sternefeld 1998, 2001 and Kobele 2006, 2010. The crucial move is to analyze constituents of the form β^i — binders — as functions from properties of assignment functions to propositions. For now, to keep things as simple as possible, I will introduce this sort of meaning via a kind of type-shifting rule that applies to moved expressions, triggered by the superscript index. (Though a more general approach, which would also allow for a directly compositional analysis of quantification, would be to analyze all expressions as functions from assignment functions to their "regular" semantic values, as Sternefeld and Kobele do.) This rule is stated in (36) (which adapts Sternefeld's semantics for generalized quantifiers), where a is the type of assignment functions and τ is any type.

about analyzing all expressions as functions over assignment functions. What may be crucial, however, is that this configuration is relevant only for $\bar{\text{A}}$-movement, since A-movement does not give rise to the same kinds of identity constraints on ellipsis (Sauerland 1998).

[8]In fact, we could just as well assume that the index is the trace. We will want to say something different about pronouns; but arguably we need to do this anyway to ensure that we don't run into problems with crossover. For now, I will assume that trace binding and pronoun binding involve distinct indexing mechanisms, along the lines proposed by Büring (2004).

(36) If $[[\beta]]^g$ is type $\langle\langle e,t\rangle,\tau\rangle$, then $[[\beta^i]]^g = \lambda p_{\langle a,t\rangle}.[[\beta]]^g(\lambda x.p(g[i/x]))$

This rule capitalizes on the fact that we can take a function from assignment functions to truth values and turn it into a function from individuals to truth values that picks out those individuals that make the original sentence true when they are returned as the value for a particular index by the assignment function, in this case the superscript index on the moved expression. This function can then be supplied as the scope argument of a generalized quantifier. For example, given the basic denotation of *every city* in (37a), we can characterize the meaning of *every city*^{i} as in (37b).[9]

(37) a. $[[\textit{every city}]]^g = \lambda f_{\langle e,t\rangle}.\forall x[\textbf{city}(x) \rightarrow f(x)]$

b. $[[\textit{every city}^i]]^g = \lambda p_{\langle a,t\rangle}.[\lambda f_{\langle e,t\rangle}.\forall x[\textbf{city}(x) \rightarrow f(x)]](\lambda x.p(g[i/x]))$
$= \lambda p_{\langle a,t\rangle}.\forall x[\textbf{city}(x) \rightarrow [\lambda x.p(g[i/x])](x)]$
$= \lambda p_{\langle a,t\rangle}.\forall x[\textbf{city}(x) \rightarrow p(g[i/x])]$

The final step is to say how a moved expression composes with its scope. As things stand, we have a type mismatch: a moved expression with a superscript index is type $\langle\langle a,t\rangle,t\rangle$, but its sister is type t. There is a simple fix, however: we just abstract over the assignment function relative to which the sister of the moved expression is interpreted. The rule is stated in (38).

(38) If $[[\beta]]^g$ is type $\langle\langle a,t\rangle,t\rangle$ and $[[\alpha]]^g$ is type t, then $[[\beta\ \alpha]]^g = [[\beta]]^g(\lambda g.[[\alpha]]^g)$

The derivation in (39b) shows the computation of truth conditions for *Polly visited every city*, assuming QR of *every city*.

(39) a. every city^i [Polly visited t_i]

b. $[[\textit{every city}^i]]^g(\lambda g.[[\textit{Polly visited } t_i]]^g)$
$= [\lambda p_{\langle a,t\rangle}.\forall x[\textbf{city}(x) \rightarrow p(g[i/x])]](\lambda g.\textbf{visit}(g(i))(\textbf{polly}))$
$= \forall x[\textbf{city}(x) \rightarrow [\lambda g.\textbf{visit}(g(i))(\textbf{polly})](g[i/x])]$
$= \forall x[\textbf{city}(x) \rightarrow \textbf{visit}(g[i/x](i))(\textbf{polly})]$
$= \forall x[\textbf{city}(x) \rightarrow \textbf{visit}(x)(\textbf{polly})]$

In effect, the rule for interpreting expressions with superscript indices builds Predicate Abstraction into the denotation of a binder, rather than characterizing it as an operation on the expression that provides the binder's scope. I have implemented here it as a type-shifting rule, but as Sternefeld and Kobele show in their work, it could just as well be recast as the meaning of the superscript index if we relativize all meanings to assignment functions. At the same time, the composition rule in (38) does not really need to be stated as an independent composition principle. If we follow Sternefeld and Kobele, then sentence denotations are already functions from assignment functions to propositions, and so can compose directly with a binder. Alternatively, if

[9] In the case of expressions whose basic type is e, I assume that they are first lifted to a type $\langle\langle e,t\rangle,t\rangle$ denotation in the usual way, then the derivation of the meaning of the superscript-indexed form is as follows:

(i) $[[\textit{Polly}^i]]^g = \lambda p_{\langle a,t\rangle}.[\lambda f_{\langle e,t\rangle}.f(\textbf{polly})](\lambda x.p(g[i/x]))$
$= \lambda p_{\langle a,t\rangle}.[\lambda x.p(g[i/x])](\textbf{polly})$
$= \lambda p_{\langle a,t\rangle}.p(g[i/\textbf{polly}])$

Relative to any assignment g, *Polly*^{i} is true of a property of assignment functions p iff p returns true for assignments just like g except that i is mapped to **polly**.

we take the more conservative approach represented by (36), we could hypothesize a general rule mapping any expression from its regular denotation to a function from assignment functions to its denotation — or even more generally, from its regular denotation to a function from some evaluation parameter for that denotation. Cook and Glanzberg (2013) observe that this is the intuition underlying the rule of "Intensional Function Application" (IFA) in von Fintel and Heim 2007, whereby an expression of type $\langle\langle s,t\rangle,t\rangle$ combines with an expression of type t by binding the world parameter relative to which its argument is evaluated, and propose that the composition of a binder and its scope be treated in the same way. (Cook and Glanzberg achieve this with a version of (35); the rule in (38) arguably captures the parallelism between binding and IFA even more directly.) Either way, the approach I have outlined here allows us to dispense entirely with binding-specific composition rules, such as Heim and Kratzer's Predicate Abstraction.

For the purpose of this paper, I will adopt (36) and (38) to implement the Predicates and Formulas Hypothesis instead of (35), though nothing really hinges on this. What is important is that, regardless of which implementation we choose, Predicates and Formulas entails that any variables inside the binder's scope that are coindexed with it, and so ultimately come to be interpreted as bound in virtue of the rules in (36) and (38) (or (35)), remain free inside this constituent. In this respect, the syntax and semantics of binding and scope-taking that I have presented here reproduces one of the results of Heim's Formulas Hypothesis, and allows us to explain the pattern of ACD data from Section 1 in the same way, provided we can also reproduce the effects of No Meaningless Coindexing. But first let me show that my analysis can handle data like Jacobson's (31a), which were problematic for Heim's account. To do this, we need to ensure that, unlike the expression that provides a quantifier's scope, the expression that provides its restriction (in particular, a relative clause) corresponds to a *predicate*, not to a formula.

In fact, we have almost everything in place to achieve this result; the final piece is an appropriate semantics for the relative operator. And given everything else I have said, the semantics is quite simple: if the relative operator is analyzed as the identity function over functions from individuals to truth values, as in (40a) (or as a suitably restricted function if we want to build in animacy restrictions, etc.), then its superscript-indexed form in (40b) effectively turns a formula into a predicate by binding all free variables that bear the index on the operator (cf. the semantics for **lambda** in Sternefeld 1998, p. 11). (41) provides a sample derivation, showing that we get exactly what we want.

(40) a. $[[wh]]^g = \lambda f_{\langle e,t\rangle}.f$

b. $$\begin{aligned}[[wh^i]]^g &= \lambda p_{\langle a,t\rangle}.[[wh]](\lambda x.p(g[x/i]))\\ &= \lambda p_{\langle a,t\rangle}.[\lambda f.f](\lambda x.p(g[x/i]))\\ &= \lambda p_{\langle a,t\rangle}\lambda x.p(g[x/i])\end{aligned}$$

(41) a. wh^i [Erik visited t_i]

b. $$\begin{aligned}&[[wh^i]]^g(\lambda g.[[Erik\ visited\ t_i]]^g)\\ &= [\lambda p_{\langle a,t\rangle}.[\lambda f.f(\lambda x.p(g[i/x]))]](\lambda g.\mathbf{visit}(g(i))(\mathbf{erik}))\\ &= \lambda f.f(\lambda x.[\lambda g.\mathbf{visit}(g(i))(\mathbf{erik})](g[i/x]))\\ &= \lambda f.f(\lambda x.\mathbf{visit}(g[i/x](i))(\mathbf{erik}))\\ &= \lambda f.f(\lambda x.\mathbf{visit}(x)(\mathbf{erik}))\\ &= \lambda x.\mathbf{visit}(x)(\mathbf{erik})\end{aligned}$$

With these assumptions in hand, let us now turn to the ellipsis facts. First, it is easy to see that we have no problem accounting for (31a): the syntactic identity condition on ellipsis is satisfied, and the contrast condition is too, because the regular semantic value of the relative clause containing the antecedent VP (42a) is a member of the focus value of the relative clause containing the elided VP (42b), assuming focus on *Erik*.

(42) a. $\lambda x.\mathbf{visit}(x)(\mathbf{polly})$
b. $\{\lambda x.\mathbf{visit}(x)(y) \mid y \text{ an alternative for } \mathbf{erik}\}$

Crucially, the fact that the two VPs contain distinct variables is irrelevant, because these variables are bound within the constituents that satisfy the contrast condition (the relative clauses). With respect to configurations like (42), then, the analysis proposed here makes the same predictions as the Predicates Hypothesis.

In contrast, the analysis makes the same predictions as the Formulas Hypothesis for ACD configurations, with one additional crucial assumption. Let's start by looking at a typical example of ACD like (43a), to which we could in principle assign either the Logical Form in (43b) or the one in (43c) (I will explain the * below); the only difference here is the index on the relative operator.

(43) a. Polly visited every city that Erik did.
b. [every city [*wh*^{1} that Erik did ~~[$_{\text{VP}}$ visit t_1]~~]]^{1} [Polly PAST [$_{\text{VP}}$ visit t_1]]
c. * [every city [*wh*^{2} that Erik did ~~[$_{\text{VP}}$ visit t_2]~~]]^{1} [Polly PAST [$_{\text{VP}}$ visit t_1]]

My account of the acceptability of ellipsis in (43a) is nearly identical to Heim's "Formulas" account, which I presented in the previous section. The contrast condition must be satisfied for non-overlapping constituents, which means that no matter what we choose for the antecedent, we will end up with an assignment-dependent meaning for the VP-internal trace. This means that the only way to ensure that the contrast condition is satisfied is for corresponding variables in the antecedent and elided VP to be identical. This is the case in (43b), because I have coindexed the trace of QR and the trace of relativization, but it is not the case in (43c), which means that this is not, in fact, a possible LF for (43a), even though it correctly represents the meaning of this sentence.

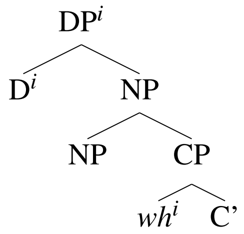
But if the trace of QR and the trace of relativization must be coindexed in order to derive a Logical Form in ACD configurations that licenses ellipsis, then clearly my analysis is incompatible with Heim's No Meaningless Coindexing constraint: in my framework, the quantificational DP and relative operator in (43b) are distinct binders. I take the fact that this constraint does not have to be stipulated — and in fact *must not* be stipulated — to be a theoretical advantage. However, at first glance, it also looks to be a significant empirical problem, since without No Meaningless Coindexing in place, we appear to lose an account of examples like (24a), repeated below as (44a).

(44) a. * Polly visited every city that was recommended in a guidebook that also recommended the city that Erik did ~~[$_{\text{VP}}$ visit]~~
b. * [every city that was recommended in a guidebook that also recommended the city [*wh*^{n} that Erik did ~~[$_{\text{VP}}$ visit t_n]~~]]^{1} [Polly PAST [$_{\text{VP}}$ visit t_1]]
c. [every city that was recommended in a guidebook that also recommended the city [*wh*^{1} that Erik did ~~[$_{\text{VP}}$ visit t_1]~~]]^{1} [Polly PAST [$_{\text{VP}}$ visit t_1]]

If No Meaningless Coindexing is in place, the LF of this example must be as shown in (44b), with *n* any index not equal to 1. Ellipsis is ruled out here because the contrast condition cannot be satisfied: since the antecedent and elided VPs contain distinct variables, and the former is free in any constituent that can be compared for ellipsis licensing, it is not the case that the regular semantic value of (a constituent containing) the former is a member of the focus value of (a constituent containing) the latter for all assignments. However, if we give up No Meaningless Coindexing — which is necessary to account for well-formed examples like (43a) — then it appears that nothing prohibits "accidentally" coindexing the embedded relative operator with the matrix DP, as in (44c). This LF satisfies the contrast condition on ellipsis for the same reasons that (43b) does, and so should license ellipsis in (44a).

Descriptively, what we want is to allow "meaningless" coindexing *only between a relative operator and the DP whose nominal head it modifies*. To derive this result, I propose that all binders are assigned a unique index — call this restriction NO COINDEXATION — *except* for the special case of relative operators, which may (and perhaps even must) bear the same index as the determiner that heads the nominal that they modify. Recall that I am treating superscript indices as features on D that project to the DP, so I want to suggest here that the apparent violation of No Coindexing in the case of a relative operator and its associated D in the configuration in (45) is actually a form of agreement, parallel to e.g. agreement in ϕ-features that also obtains between relative operators and the head of the nominal they modify.

(45)



In particular, the idea behind No Coindexation is not that it is a constraint on representations of any sort, but is rather just the way the grammar works. An expression can enter the derivation with a superscript index or not — and this determines whether it can be interpreted as a binder, given the rule in (36) — but if it does bear a superscript index, then the index is unique. In addition some expressions, including but perhaps not limited to relative pronouns, can (and perhaps must) be assigned a superscript index feature under local agreement with D.

With these assumptions about indexing in place, the parse in (44c) is ruled out. No Coindexation entails that the DP *the city ...* bears a distinct index from the DP *every city...*, which in turn means that the relative operator that binds the trace inside the elided VP also bears a distinct index from the DP *every city...*, and finally that the corresponding variables inside the two VPs are distinct. This leaves the parse represented by (44b) as the only option, and ellipsis is correctly ruled out for the reasons we have already seen: the contrast condition cannot be satisfied.

4 Beyond the basic cases

4.1 Identity of nominal content

Sauerland (1998, 2004) develops an analysis of the facts in Section 1 that is distinct from the approach I have advocated here (and from Heim's), and so deserves some discussion. The crucial component of Sauerland's analysis is his treatment of the syntax and semantics of $\overline{\text{A}}$-chains. First, Sauerland crucially adopts an analysis of $\overline{\text{A}}$-chains as "copy and delete" structures, such that the trace of $\overline{\text{A}}$-movement contains a copy of the nominal head of the moved phrase, which I will represent as $\langle$NP$\rangle$ (Chomsky 1995, Sauerland 1998, Fox 1999b, 2002). The interpretation rule for copies is stated in (46) (cf. Fox 1999b).

(46) $[[\langle \text{NP}_i \rangle]]^g = g(i)$ if $[[\text{NP}]]^g(g(i)) = 1$, else undefined.

On this analysis, the unacceptability of (47a) is explained as a failure of identity due to conflicting requirements imposed by the traces (copies) in the antecedent and elided VPs. (47b) shows the Logical Form of this example, which I represent using a Predicates Hypothesis approach to binding, as in Sauerland 2004.

(47) a. * Polly visited every major city that is located in a country Erik did.

b. every major city that is located in a country [2 that [Erik did ~~[$_{\text{VP}}$ visit $\langle$country$_2\rangle$]~~]] [1 [Polly PAST [$_{\text{VP}}$ visit $\langle$major city$_1\rangle$]]]

According to (46), the lexical content of the traces has to be factored into the meaning computation as restrictions on the values of the variables contributed by the traces. This means that when we compute the meanings of the constituents that could, in principle, satisfy the contrast condition on ellipsis — the regular semantic value of the scope of the matrix quantifier (the index-1 structure in (47b)), and the focus value of the relative clause containing the elided VP (the index-2 structure) — we must factor in these restrictions. The results are as shown in (48a-b), respectively; (48a) is not an element of (48b) because of the restriction introduced by the copy, and ellipsis is ruled out.

(48) a. $\lambda x : \textbf{major-city}(x).\textbf{visit}(x)(\textbf{polly})$

b. $\{\lambda x : \textbf{country}(x).\textbf{visit}(x)(y) \mid y \text{ an alternative to } \textbf{erik}\}$

A prediction of this analysis is that ellipsis in examples that are structurally parallel to (47a) should be acceptable just in the case that the two traces introduce identical lexical content, and this is indeed what Sauerland argues, based on data like the following (these are Sauerland's judgments):

(49) a. * Polly visited every town that is near the lake that Erik did.

b. Polly visited every town that is near the town that Erik did.

c. Polly visited every town that is near the one Erik did.

(50) a. * Erik ordered a drink that was more expensive than the dish that Polly did.

b. Erik ordered a drink that was more expensive than the drink that Polly did.

c. Erik ordered a drink that was more expensive than the one that Polly did.

However, my own judgments partially differ: I find the (b) examples above only marginally more acceptable than the (a) examples, though I do indeed find a clearer distinction between the (c) examples and the (a)/(b) examples. And indeed there seems to be variability in the data: some speakers that I have consulted share my judgments, and others agree with Sauerland's.

One factor that seems to be crucial is definiteness. In all of the examples that Sauerland discusses in which identity of nominal content improves acceptability, the second DP is definite, and in the most acceptable examples, it involves anaphoric *one*. If we modify the examples slightly so that the second DP is indefinite, acceptability clearly declines, even with shared nominal content. Consider, for example, the examples in (51), uttered in a context in which they describe the results of a cognitive psychology experiment in which the task is for one subject to reproduce the actions of another when facing a board covered with different shapes (circles, squares, triangles).

(51) a. * Sterling touched every circle that was located above a circle that Julian did.
b. * Sterling touched every circle that was located above some circles that Julian did.
c. * Sterling touched every circle that was located above two circles that Julian did.
d. * Sterling touched every circle that was located above no circles that Julian did.

Descriptively, the less definite the second DP, the less acceptable is ellipsis, even when we have identity of nominal content.The following examples make a similar point:

(52) a. Polly will order anything Erik does.
b. * Polly will order anything that goes well with something Erik does.

(53) a. Erik will support anyone Polly does.
b. * Erik will support anyone who is recommended by someone Polly does.

If mismatch in lexical content of traces is the key factor in explaining the pattern of acceptability in ACD that we have been examining in this paper, then (52b) and (53b) present clear problems, since *anything* and *something* do not have any nominal content that would trigger a mismatch.

My conclusion from these facts is that it is not that mismatching lexical content rules is what makes the bad examples bad; instead, it is that the definiteness of the embedded DP, which is strongest in the case of identity of lexical content or anaphoric *one* because we are talking about the same things, provides way of making bad configurations good. I see two options for accounting for the role of definiteness. One possibility is that this somehow allows for a parse in which the embedded relative operator is coindexed not with its local DP, in accord with No Coindexation and the agreement principle I proposed in the previous section, but rather with the higher DP, as shown in (54)

(54) [every town that is near [the one wh^{1} Erik did ~~[$_{\text{VP}}$ visit t_1]~~]^{2}]^{1} [Polly PAST [$_{\text{VP}}$ visit t_1]]

Ellipsis is licensed here, as we saw above; the question that needs to be answered is why the exceptional indexing is allowed, and what role definiteness plays in licensing it. One possibility, suggested to me by Jason Merchant, is that since the local DP is definite and not in contrast in the identity cases, it can be interpreted directly in its argument position: it does not need to take scope. This in turn means that it does not need a superscript index, and so relative operator is free to agree with the higher DP. This is not an option in the examples in (51), because here the lower DP is quantificational and therefore must take scope.

Another possibility, suggested to me by Polly Jacobson, is that the improvement observed in the examples in which the embedded DP is definite stems from the fact that use of the definite sets up a presupposition that there are pairs of objects and individuals connected by some salient relation, and that when we have identity of lexical content, it is particularly easy to pick out the relation expressed by the main verb as the one involved in satisfying the presuppositions of the definite. On this view, ellipsis is these examples need not be licensed by a relation to the meaning of the matrix VP, as in typical cases of ACD, but by the background context that licenses the definite description. In effect, these cases involve a kind of "contextual" rather than "linguistic" antecedent for ellipsis, something that is possible but generally dispreferred (see Hankamer and Sag 1976, Sag and Hankamer 1984 and much subsequent work), explaining the variability of the judgments.

Before concluding this discussion, let me also raise one theoretical challenge for the general hypothesis that the lexical content of traces should be relevant for the calculation of identity in ellipsis in the first place. One potential argument against this position comes from the absence of lexical content effects in cases of sloppy identity involving pronouns with different gender or number features, such as (55a-b).

(55) a. Julian touched his nose, and Mathilda did ~~[$_{VP}$ touch her nose]~~ too.
b. Julian touched his nose, and the girls did ~~[$_{VP}$ touch their noses]~~ too.

The semantic contribution of number and gender features on pronouns is usually analyzed in the same way as the lexical content of traces in Sauerland's analysis: these features restrict the domain from which the value of the variable contributed by the pronoun may be selected. For example, the denotations of *his*, *her* and *their* can be defined as in (56a-c) (cf. Heim and Kratzer 1998, p. 244).

(56) a. $[[his]]^g = g(i)$ if $g(i)$ is a male atomic individual, else undefined.
b. $[[her]]^g = g(i)$ if $g(i)$ is a female atomic individual, else undefined.
c. $[[their]]^g = g(i)$ if $g(i)$ is a plural individual, else undefined.

If the domain restrictions imposed by number and gender features played a role in licensing ellipsis, just like the lexical content of traces in Sauerland's analysis, then we would incorrectly predict that the sloppy interpretations of the pronouns indicated in (55a-b) should be impossible. One conclusion we could draw, then, is that this sort of information is simply not relevant to the calculation of identity in ellipsis, in which case Sauerland's explanation of argument identity effects disappears.

There is an alternative response to this problem, however, advocated by von Stechow (2003) (see also Kratzer 1998, 2009). Von Stechow proposes that number and gender features on bound pronouns may be deleted at LF, leaving a pure variable behind. According to von Stechow, this is independently necessary to account for the possibility of a "sloppy" interpretation of the first person pronoun in (57), paraphrased in (57a). (Von Stechow refers to unpublished work by Irene Heim for the initial observation of this problem and an alternative "feature agreement" mechanism to solve it; cf. Kratzer 1998, 2009.)

(57) Only I touched my nose.
a. No x other than the speaker is such that x touched x's nose.
b. No x other than the speaker is such that x touched the speaker's nose.

If the first person pronoun *my* restricted its value to the speaker of the sentence, then only the "strict" interpretation in (57b) should be available. The fact is that (57) is ambiguous, however, having both the strict interpretation in (57b) and the sloppy interpretation in (57a).

If von Stechow's proposals are correct, they would eliminate the problem presented by number and gender mismatch in sloppy interpretations of ellipsis. However, they raise a new question for Sauerland's analysis: if the lexical content of bound pronouns can be deleted at LF, then why can't the lexical content of bound traces be deleted? Arguably, the latter information is even more redundant than the former, since there is a full copy of the trace elsewhere in the representation (the head of the relative clause).

4.2 Pied-piping

In addition to the data we have already discussed (see (58) above), Jacobson (1998) introduces a second set of facts which she believes to be problematic for a variable-based analysis of ACD, and which call into question the descriptive generalization in (11). Specifically, Jacobson shows that it is possible to have distinct internal arguments of an elided and antecedent VP in ACD configurations when the object of the elided verb is pied-piped, as in (58).

(58) Polly visited every country the capital of which Erik did.

Jacobson provides a variable-free analysis of the pied-piping data, which I will describe in more detail below, that neatly accounts for the facts. However, as I noted earlier, her analysis does not account for the pattern of ACD discussed in Section 1. My goal in this subsection is to show that the analysis that I have developed in this paper not only accounts for the pattern we started out with and examples like Jacobson's (31), it also accounts for the interaction of ACD and pied-piping.

At first, it looks as though (58) is not a problem for the analysis I have developed in this paper. Let us assume first that pied-piping structures are interpreted without reconstruction, and second that the index-agreement relation that I proposed at the end of Section 3 is a purely syntactic constraint that holds between any XP in SpecCP and a higher D, regardless of whether that XP is a lexical *wh*-expression or not. This gives us (59) as a candidate LF for (58).

(59) [every country [the capital of which]^{1} Erik did $\cancel{[_{\mathrm{VP}}\ \text{visit}\ t_{1}]}$]^{1} [Polly PAST [$_{\mathrm{VP}}$ visit t$_{1}$]]

Since the VP-internal variables are the same here, the contrast condition will be satisfied for the elided and antecedent VPs, just as in standard cases of ACD. (Assuming, of course, that we can also provide the right denotation for the relative clause given the pied-piping configuration!)

The problem comes from a second set of facts discussed by Jacobson. Any analysis of ACD that has the basic characteristics of the one I have adopted here — one that adopts Rooth's licensing condition and makes crucial use of variables — predicts that in examples that are just like standard cases of ACD except that the internal argument is overtly preposed, ellipsis of either the embedded or matrix VP should be possible. This follows from the fact that ellipsis can be licensed strictly on the basis of an appropriate contrast relation between the elided and antecedent VPs, as we have seen. And indeed, (60a-b) suggest that this prediction is correct.

(60) a. Any country that Erik does, Polly visits.
b. Any country that Erik visits, Polly does.

Now let us consider examples involving pied-piping, like (58). If they have the analysis sketched above, then it seems that the prediction is that they should behave just like (60a-b) in preposing. However, as Jacobson shows, this is not the case: when the object DP in (58) is preposed, only the embedded VP may be elided. This is illustrated by the contrast in (61).

(61) a. Any country the capital of which Erik does, Polly visits.

b. * Any country the capital of which Erik visits, Polly does.

In fact, however, both (58) and (61a-b) can be accommodated within the framework developed in this paper, though we will need to slightly modify the licensing condition on ellipsis from Rooth 1992 that I have made use of so far. Let us first assume, contrary to what I assumed above, that pied-piped XPs undergo reconstruction. On this view, the LF of the ACD example in (58) is (62).

(62) [every country which^{1} Erik PAST ~~[$_{\text{VP}}$ visit the capital of t_1]~~]^{1} [Polly PAST [$_{\text{VP}}$ visit t_1]]

Let us further assume, following Jacobson 1998, that the denotation of a relational DP like *the capital of x* includes a function of type $\langle e,e\rangle$ applied to an individual, where the function comes from the head noun *capital* and its argument comes from the object of the preposition *of*. We may now check to see whether the appropriate contrast condition is satisfied, starting with the elided and antecedent VPs. As Jacobson also shows, in an example like (62), *capital* must be focused, which means that the focus value of the elided VP is (63a) and the regular semantic value of the antecedent VP is (63b).

(63) a. $\{\lambda x.\mathbf{visit}(f(g(1))(x) \mid f \in D_{\langle e,e\rangle}\}$
b. $\lambda x.\mathbf{visit}(g(1))(x)$

According to Jacobson, (63b) is a member of (63a), since it is equivalent to the function in (64), where **id** is the identity function on individuals (one of the many functions of type $\langle e,e\rangle$).

(64) $\lambda x.\mathbf{visit}(\mathbf{id}(g(1)))(x)$

This is not quite enough to license ellipsis under the current set of assumptions, however. Recall that the version of Rooth's theory adopted in Section 2 actually requires that two conditions be satisfied in order to license deletion: a constituent that contains the deleted VP must contrast appropriately with a constituent that contains its antecedent, and the deleted VP itself must contain the same lexical/syntactic material as the antecedent. In the example under discussion, only the former condition is met: if we reconstruct the pied-piped DP, the syntactic identity condition is clearly no longer satisfied.

In fact, however, there is a growing body of evidence that ellipsis is not subject to a lexical/syntactic identity condition at all, but can (and should) be explained strictly in terms of semantic identity. The most compelling arguments for this position come from Merchant (2001), who documents a range of cases in which formal identity can be sacrificed in ellipsis as long as semantic identity holds, among which are Fiengo and May's (1994) "vehicle change" effects, finite-nonfinite mismatches in sluicing, etc. (Though see Merchant 2008 for data which are problematic for a fully semantic licensing condition on ellipsis.) For our purposes, we may assume the version of Rooth's analysis developed in Fox 1999a, which is essentially the same as the one introduced in Section 2 except that it eliminates the lexical identity condition. If appropriate contrast (Fox's PARALLELISM) is enough to license deletion, then the analysis of (58) described above goes through.

Turning to the preposing examples, it should be clear that (61a) follows straightforwardly, since its LF will be just like that of (58) (again, assuming that the pied-piped DP is reconstructed). (61b) is the interesting case. According to the assumptions I have laid out here, it should have a LF like (65).

(65) [Any country [which^1 Erik PRES [$_{VP}$ visit the capital of t_1]]]^1 [Polly does ~~[$_{VP}$ visit t_1]~~]

In (65), the elided and antecedent VPs are reversed, so we now need to check whether the regular semantic value of the embedded VP (or a constituent that contains it) is a member of the focus value of the matrix VP (or a constituent that contains it). It is enough just to look at the regular semantic value of the antecedent VP — which will necessarily be a part of the semantic value of any constituent that contains it — to see that this condition will never be satisfied:

(66) $\lambda x.\mathbf{visit}(\mathbf{capital}(g(1))(x)$

This VP contains the meaning of the reconstructed DP *the capital of* t_1, and so will necessarily differ in meaning from any possible focus value based on a VP of the form *visit* t_1. Appropriate contrast therefore fails, and ellipsis is correctly predicted to be impossible.

4.3 Partitives

I want to conclude with a look at a couple of examples that bear some similarity to pied-piping structures, one of which introduces a final puzzle, the solution to which may provide further support for the analysis I have developed in this paper. These involve ACD in partitive DPs, such as (67a-b).[10]

(67) a. Polly read each of the books Erik did.
b. Polly read 10 pages of every book Erik did.

These examples are superficially similar, but there is an important difference. In (67a), the semantic head is *each*, and the expression after *of* must be a definite plural: we cannot replace *the books Erik did* with *every book Erik did*. The most straightforward semantic analysis is one in which the definite denotes a plural individual, and the partitive turns it into a property of parts of the plurality, which then provides the restriction for *each*. We can explain the acceptability of ACD here by simply assuming that the definite DP does not bear a superscript index since it is referential (cf. the Merchant-style explanation of the role of definiteness in the Sauerland identity effects), and so the relative operator inherits the index from *each*, as shown in (68).

(68) [each of the books [wh^1 Erik did ~~[$_{VP}$ read t_1]~~]]^1 [Polly PAST [$_{VP}$ read t_1]]

Examples like (67b), however, in which the higher "determiner" is a measure expression and the DP after *of* is quantificational, are more complicated. In fact, such examples appear to be ambiguous. One reading, which says that Polly read 10 pages of every book that Erik read 10 pages of, is represented by the LF in (69a) and is not a problem: the quantificational DP takes scope, leaving the measure portion of the partitive inside the VP, and the elided VP contains a second occurrence of the measure term (cf. the discussion of "NP-contained ACD" in Kennedy 1997).

(69) a. [every book *wh*^{1} Erik did ~~[$_{VP}$ read 10 pages of t_1]~~]^1 [Polly PAST [$_{VP}$ read 10 pages of t_1]]

[10]Sauerland (2004) discusses examples like (67a), citing 1997 MIT lecture notes by Irene Heim as the first discussion of their relevance for the analysis of the ACD facts we have been concerned with here.

b. [every book *wh*^{1} Erik did ~~[$_{VP}$ read t_1]~~]^1 [Polly PAST [$_{VP}$ read 10 pages of t_1]]

But there appears to be a second reading which says nothing about how much of the books Erik read, which we might assume to be represented by the LF in (69b). The problem is that ellipsis should be impossible here, for the same reason that it was ruled out in (61b): since the antecedent VP includes material that is absent from the elided VP (the measure expression), there is no way that the meaning of the former will be part of the focus value of some constituent that includes the latter.

We might try to fix things by hypothesizing that the entire partitive DP takes scope. However, since the complement of *of* is quantificational, it also must take scope, giving us a Logical Form along the lines of (70).

(70) [every book *wh*^{1} Erik did ~~[$_{VP}$ read t_1]~~]^1 [10 pages of t_1]^2 [Polly PAST [$_{VP}$ read t_2]]

No Coindexing dictates that the indices on the two binders must be distinct, as indicated in (70). Assuming that the index on the relative operator must agree with its local D, this in turn means that the corresponding traces in the elided and antecedent VPs bear distinct indices, and so ellipsis is ruled out for the same reasons that the analysis I have developed in this paper rules out the unacceptable instances of ACD that we began with in Section 1.

(67b) therefore looks like a problem for my proposals, but I actually think it may provide surprising support for the analysis. Note that *read 10 pages of x* has a "lower-bounded" reading: it can be understood either as true of those individuals who read exactly 10 pages of *x* or as true of those individuals who read 11 pages of *x*, 12 pages of *x*, most of *x*, all of *x*, and so forth. This means that the ambiguity of (67b) might not be a real ambiguity, and that in fact only (69a) is the actual LF of this example, since the domain of quantification here also includes the (10-plus page) books that Erik read entirely. If this is the case — if the measure terms must appear in both the antecedent and elided VPs — then readings corresponding to (69b) should disappear when the measure term introduces an upper bound. The following examples appear to support this prediction:

(71) a. Polly read exactly 10 pages of every book Erik did.
b. Polly read less than half of every book Erik did.
c. Polly read at most two sections of every book Erik did.

To my ears, these examples only have truth conditions that correspond to the LF in (69a), i.e., they are understood as though the measure terms are included in the meanings of both the antecedent and elided VPs. (71a), for example, tells us only that Polly read exactly 10 pages of every book Erik read exactly 10 pages of; it tells us nothing about how much she read of the books that Erik read entirely. If this pattern is robust, then these examples actually provide unexpected support for the overall account of identity effects in ACD that I have developed in this paper, since it correctly rules out what otherwise looks like an easily derivable reading for these sentences.[11]

[11] It may still be the case that the measure terms in these examples must take scope; this is what I would assume based on recent studies of these expressions (see e.g. Nouwen 2010, Beck 2012, Kennedy to appear, 2013), though I would also want to claim that the partitive semantics remains inside the VP, at least for incremental verbs like read (see Kennedy 2012). What the analysis I have developed in this paper predicts, and what the facts in (71) appear to indicate, is only that if the measure expressions do take scope, then they take scope no higher than the constituents that are compared for ellipsis licensing, e.g. at the VP.

5 Conclusion

This paper has argued for a compositional analysis of quantification/variable binding structures in which binders are analyzed as second order properties of assignment functions, and the expressions that provide their scope are analyzed as functions from assignment functions to truth values, as in Sternefeld 1998, 2001, Kobele 2006, 2010. The relation between a binder and its scope is therefore a version of what Heim (1997) calls the Formulas analysis, and the compositional interpretation of binding structures can be stated without reference to syncategorematic rules such as Heim and Kratzer's (1998) rule of Predicate Abstraction. At the same time, these very same assumptions about binding, combined with a semantic analysis of relative operators as identity relations on functions of type $\langle e,t\rangle$, ensures that the semantic type of a relative clause is type $\langle e,t\rangle$, thus permitting a semantics for quantifier restrictions that is in line with what Heim calls the Predicates analysis. I called this hybrid account of the syntax and semantics of quantification and binding the "Predicates and Formulas" analysis, and I showed that it correctly explains not only the complex pattern of identity effects in Antecedent Contained Deletion constructions first discussed in Kennedy 1994 and Heim 1997, but also the various elaborations of and (apparent) exceptions to pattern that have been discussed in subsequent literature, in particular in Jacobson 1998 and Sauerland 2004.

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