A “Variety” Analysis of Anaphorical Expressions

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Abstract

In this paper I propose an extension of a dynamic semantics with choice functions in order to describe how a variety of possible anaphorical expressions refer to one and the same antecedent in a uniform way. In the mini-discourse *A farmer walks. X whistles* we can replace *X* by different anaphorical expressions: *he, the farmer who walks, the farmer, the man, the man who walks,* and *the walker*. In order to account for this variety, I define the meaning of a sentence *an F is G* as its potential to change the values of the choice function or “representatives” for the following sets: the set of Fs and its supersets and their intersections with the set of G. Thus, all mentioned anaphorical expressions are resolved to refer to the same object, although via different, but connected sets.

1. Anaphorical Reference

Anaphorical expressions are one of the most important tools for creating coherent texts. There is a great variety of these expressions connecting terms of time, space or content in a discourse. In this paper I shall only analyze anaphorical relations that connect expressions of individuals or objects. But even in this restricted domain, there are several different strategies that can create an anaphorical linkage to the antecedent expression, as illustrated in (1a-f). The form *walker* is analyzed as a short form of the more complex *a thing/person that walks.*

(1a) A farmer walks. *He* whistles.
(1b) A farmer walks. *The farmer who walks* whistles.
(1c) A farmer walks. *The farmer* whistles.
(1d) A farmer walks. *The man* whistles.
(1e) A farmer walks. *The man who walks* whistles.
(1f) A farmer walks. *The walker* whistles.

The first sentence introduces a new object into the discourse, and the second refers back to this object or referent by a different expression, which can be classified according to the groups (i)-(iv):

(i) In (1a) the pronoun *he* in the second sentence refers to the indefinite NP *a farmer* (of course, another reference of the pronoun is also possible). The use of anaphorical pronouns is restricted in several ways. Since they do not contain any descriptive material, they can only be used in the direct environment of the antecedent expression.

(ii) Definite NPs that are reconstructed with material from the antecedent sentence can differ in the amount of material they incorporate into the definite NP, as illustrated in (1b) and (1c).

(iii) Definite NPs can also be built with material other than that given in the antecedent sentence.

(iv) A special case is constituted by (1f) in which the object introduced by an indefinite NP is anaphorically linked to an definite NP that consists exclusively of material from the predicate of the antecedent sentence.

In general, current theories give different analyses for the cases (i) and (ii) and no analysis for (iii) and (iv). Centering on anaphora like (i) or on anaphora like (ii), two main groups of theories have been developed: dynamic theories represent anaphora by bound variables, whereas E-type theories assume that anaphorical expressions can be analyzed as definite descriptions.

2. Anaphora as Binding

The discussion about the nature of anaphora is one of the central topics of semantic investigations since the time of the ancient Greeks. In modern times, the controversy started again with the debate between Geach and Evans. In the discussion of medieval reference theories (supposition theories), Geach (1962) represents anaphorical pronouns as bound variables in predicate logic. He extends the representation of anaphorical pronouns inside a sentence to discourse pronouns, since he assumes that anaphorical pronouns behave like bound variables in predicate logic. This assumption is motivated by the very simple concept of representing coreferential expressions with the same bound variables as in (2) and (3):

(2) Every car owner thinks that he has the most beautiful car.

(2a) $\forall x\ [car\_owner(x) \rightarrow thinks(x, has(x, c))]$

(3) Some bicyclist fears that he drives to fast.

(3a) $\exists x\ [bicyclist(x)\ \&\ fear(x, drive\_fast(x))]$

Extending this view, he represents the two sentences in (4) by the PL-formula (4a) using the same bound variable for representing the anaphorical linkage:

(4) A man walks. He whistles.

(4a) $\exists x$ [man(x) & walks(x) & whistle(x)]

(5) If a farmer owns a donkey, he feeds it.

(5a) $\forall x \forall y$ [(farmer(x) & donkey(y) & own(x, y)) $\rightarrow$ feed(x, y)]

There are two main problems with this analysis, which were already formulated by Evans (1977): (i) How can we extend the scope of the existential quantifier across the sentence border? In predicate logic, the scope is confined to the sentence. (ii) What are the semantic rules that govern the coindexing or the use of the same variable? In (4a) we have represented the anaphorical pronoun by the variable *x* which happens to be the one that is bound by the existential operator. However, if we would have used *y* no binding would have been possible. Concerning the first question, a new family of semantic theories has been developed, the so called “discourse representation theories” (cf. Kamp 1981, Heim 1982). These theories assume an additional level of representation which gives structural information about a whole discourse. Each sentence adds new information to the discourse representation, and subsequent sentences are interpreted according to this modified context or information state. The discourse representation for sentence (4) is (4b) and for (5) it is (5b). Such representation consists of the discourse referents and conditions. They are interpreted by a mapping function into a model and they are equivalent to the corresponding PL formulas. The pronoun *he* introduces a new discourse referent, here d_2, which is identified with an already existent discourse referent, here d_1.

(4b) $\{d_1 \mid man(d_1)\ \&\ walks(d_1)\}$

(4c) $\{d_1, d_2 \mid man(d_1)\ \&\ walks(d_1)\ \&\ whistles(d_2)\ \&\ d_1 = d_2\}$

(5b) $\forall \{d_1, d_2 \mid farmer(d_1)\ \&\ donkey(d_2)\ \&\ own(d_1, d_2)\}\ \{d_1, d_2 \mid feed(d_1, d_2)\}$

Dynamic predicate logic (Groenendijk & Stokhof 1991) can be understood as a monostratal variant of discourse representation theories. It uses the classical inventory of predicate logic, but with a different interpretation. The meaning of sentences is their potential to change information, or more formally, it is a relation between two information states. Information states consist of discourse referents or variables and predicates assigned to these variables. Dynamic theories have solved the first puzzle of how to extend the scope of the existential quantifier. However, they have not solved the second problem. They need the extra-semantic process of coindexing before the semantic analysis can start (cf. Peregrin & von Heusinger 1995 for a detailed critique).

3. Anaphora as Definite Descriptions

The E-type approach was first developed by Evans (1977) among others as an alternative to the bound variable approach. After languishing for more than a decade, it was revived (e.g. Neale 1990). In E-type theories anaphorical pronouns that are outside of the quantifier antecedent phrase are represented as definite descriptions as in (4d) and (5c):

(4d) $\exists x\, [man(x) \,\&\, walk(x)] \,\&\, whistle(\iota x\, [man(x) \,\&\, walk(x)])$

(5c) $\forall x\, [(farmer(x) \,\&\, \exists y\, [donkey(y) \,\&\, own(x, y])$
$\rightarrow feed(x, \iota y\, [donkey(y) \,\&\, own(x, y]]$

This view preserves as much as possible from the classical view; it stresses the familiarity between anaphorical pronouns and anaphorical definite NPs. The two most obvious problems are the uniqueness condition of the Russellian definite description and the construction rule of the definite description representing the anaphorical pronoun. Neale (1990, 180ff) states the following construction rule for E-type pronouns:

(6) If x is a pronoun that is anaphoric on, but not c-commanded by, a nonmaximal quantifier '[Dx: Fx]' that occurs in an antecedent clause '[Dx: Fx](Gx)', then x is interpreted as '[the x: Fx & Gx]'

It is not clear what kind of rule (6) represents – a heuristic principle, a pragmatic strategy or a linguistic rule. Neale admits (1990, 184) that this is an open question, but considers it as a linguistic rule that acts on the level of logical form for the sake of argument (cf. also note 41, p. 260f. where he relativizes this view). However, it remains open whether it is a transformational or semantic rule. The other obstacle of the E-type approaches is the uniqueness condition of the Russellian analysis of definite description. In a situation where we have farmers with more than one donkey the representation (5b) becomes false, contrary to our intuitive understanding of the sentence (5). Therefore, we need a more flexible analysis of definiteness, namely the salience approach.

4. Definiteness and Salience

The salience theory of definiteness has three historical sources: first, Lewis (1979) criticizes Russell’s theory of descriptions and sketches an alternative theory using a salience ranking instead of Russell’s uniqueness condition. Second, the investigations of the Prague School (cf. Sgall et al. 1973) developed an information structure of a sentence, the pragmatic background of which is a hierarchy of “activated” referents. Third, research in artificial intelligence showed that discourse models need a structure or hierarchy of referents that is very similar to Lewis’ concept of salience (cf. Grosz & Sidner 1985).

Lewis (1979, 178) develops the concept of salience in the philosophical and linguistic discussion of the Russellian theory of descriptions. A definite NP refers uniquely according to the more general principle of *salience*:

> The proper treatment of description must be more like this: ‘the F’ denotes x if and only if x is the most salient F in the domain of discourse, according to some contextually determined salience ranking.

The Prague School has developed a similar approach in their dynamic view of the information expressed in a sentence. In this approach, the “stock of shared knowledge” (Sgall et al. 1973, 70) constitutes the common background of the speaker and the hearer. It is the set of potential referents for definite expressions. This set is further divided into background and foreground information, which depends on encyclopedic knowledge, context information and thematic structure of the sentence. Besides this dichotomy, there is a further structure described in the following way (Sgall et al. 1973, 70f.):

> There is no clear-cut dichotomy in the stock of shared knowledge, and it would be, probably, more adequate to work here with a kind of ordering than with two subclasses. Let us remark that the mentioning of an element of the stock of shared knowledge brings this element into the foreground of the stock, and, in some respects, it is possible to conceive the last mentioned element to be more foregrounded that the elements mentioned before, the foregrounding of which already shades away step by step, if it is not supported by some specific moments due to the given situation.

Computational analyses of discourse assume additional structures for discourse models in the form of a hierarchy. Such analyses treat referential process on a par with the representation of the discourse in structured models. According to Grosz & Sidner (1985, 3), a general discourse model consists of three components: “a linguistic structure, an intentional structure, and an attentional state.” The third component encodes the dynamic hierarchy between the different discourse objects. Grosz & Sidner (1985, 9) define them in the following way:

> The third component of discourse structure, the attentional state, is an abstraction of the participants’ focus of attention as their discourse unfolds. The attentional state is a property of discourse, not of discourse participants. It is inherently dynamic, recording the objects, properties, and relations that are salient at each point in the discourse.

In contrast to the Praguian approach, this structure does not depend on the hearer or speaker, but it is a property of the context (as in Lewis’ view). Webber (1983, 335) distinguishes between the act of reference by the speaker, and the referential behavior of expression in a certain discourse:

> That is, “referring” is what people do with language. Evoking and accessing discourse entities are what texts/discourses do. A discourse entity inhabits a speaker’s discourse model and represents something the speaker has referred to. A speaker *refers* to something by utterances that either *evoke* (if first reference) or *access* (if subsequent reference) its corresponding discourse entity.

5. Choice Functions and Dynamic Interpretation

The concept of salience was never formally reconstructed although it was often regarded as an essential part for fixing the referent of definite expressions. In this section I develop a formal reconstruction of salience by means of context dependent choice functions. As formal semantem we will use the epsilon operator that was introduced into metamathematics by Hilbert & Bernays (1939). The epsilon operator is interpreted by a choice function that assigns to each non empty set one of its elements and to the empty set an arbitrary element. Thus, the choice function selects the first element of an ordered set. The classical epsilon calculus has been extended in two ways. First, Egli (1991) introduced a family of choice functions instead of one fixed choice function as used by Hilbert & Bernays. In a second extension, Peregrin & von Heusinger (1995) embedded the approach into a dynamic framework. In the remainder of this section I summarize this dynamic choice functions approach.

Let us assume the non-empty universe U of individuals. An epsilon function (or a choice function) f is a partial function from the power-set of U into U such that $f(s) \in s$ for every $s \subseteq U$ for which f is defined. This means that the class EPS_U of all epsilon functions based on U is defined as follows (where D(f) and R(f) denote the domain and the range of f, respectively):

DEF1. $EPS_U = \{f \mid D(f) \subseteq Pow(U) \text{ and } R(f) \subseteq U \text{ and } f(s) \in s \text{ for every } s \in D(f)\}$

We further introduce update functions for epsilon functions, or epsilon updates in short. An epsilon update is a function that takes three arguments: an epsilon-function, an element of the universe, and a subset of the universe; it yields a new epsilon function.

DEF2. $UPD = \{f \mid D(f) = EPS x U x Pow(U) \text{ and } R(f) \subseteq EPS\}$

The basic epsilon-update upd_1 applied to an epsilon function e, an individual d, and a set s, yields the epsilon function e' which is identical with e except for the assignment d for the set s.

DEF3. upd_1 is the element of UPD defined as follows

$$upd_1(e,d,s)(s') \quad = d \text{ if } s'=s \text{ and } d \in s$$
$$= e(s') \text{ otherwise}$$

We use $e'=e^s$ as an abbreviation for $\exists d.e'=upd_1(e,d,s)$. If $e_2=e_1{}^s$ and $e_3=e_2{}^{s'}$, then we also write $e_3=e_1{}^{s,s'}$. upd_1 can be seen as the first approximation to the salience change potential of an indefinite NP: The indefinite NP *a man* selects an arbitrary man and changes the actual choice function such that this arbitrarily chosen man becomes the current representative for the class of men. In the following, a formal fragment will be defined illustrating how choice functions act in a dynamic semantics. I do without quantifiers, since they play no role in the argument. However, for a detailed treatment of quantifiers in this framework see Peregrin & von Heusinger (1995).

DEF4a. (lexicon)

1. sentences
2. terms (constants **he, she, it**)
3. n-ary predicates for n>0 (constants **man, walk, whistles, farmer, boring, woman, thing** for n=1; **own, beat** for n=2)
4. determiners (constants **a, the**)
5. n-ary logical operators for n=1,2 (the constant ¬ for n=1; **&, v** for n=2)

DEF4b. (syntax)

1. If P is a unary predicate and D a determiner, then D(P) is a term.
2. if $T_1,...,T_n$ are terms and R an n-ary predicate, then $R(T_1,...,T_n)$ is a sentence.
3. If S is a sentence and o a unary logical operator, then oS is a sentence.
4. If S_1 and S_2 are sentences and o a binary logical operator, then S_1oS_2 is a sentence.

DEF4c. (semantics)

A model is a pair <U,|| ||>, where U is a set and || || is a function such that (i) if T is a term, then $||T||\in U$; (ii) if R is an n-ary predicate, then $||R||\in U^n$. If T is a term and $e\in EPS_U$, then we define the value $||T||_e$ in the following way:

$||T||_e$ = ||T|| if T is a constant term

= e(||P||) if T is D(P) for a determiner D and a predicate P

The function || || is extended to the categories of terms and sentences so that if E is a term or a sentence, then $||E||\subseteq EPSxEPS$:

1a.	$\|\|$**a**(P)$\|\|$ = $\{<e,e'>\mid e'=e^{\|\|P\|\|}\}$
1b.	$\|\|$**the**(P)$\|\|$ = {<e,e'>| e'=e and e'(||P||) is defined}
1c.	||**he**|| = ||**the(man)**||
1d.	||**she**|| = ||**the(woman)**||
1e.	||**it**|| = ||**the(thing)**||
2.	$\|\|P(T_1,...,T_n)\|\| = \{<e,e'>\mid$ there exist $e_0,...,e_n$ so that $e=e_0$ and $e'=e_n$ and $<e_0,e_1>\in \|\|T_1\|\|$ and ... and $<e_{n-1},e_n>\in \|\|T_n\|\|$ and $<\|\|T_1\|\|_{e1},...,\|\|T_n\|\|_{en}>\in \|\|P\|\|\}$
3.	$\|\|\neg S\|\| = \{<e,e'>\mid$ e=e' and there is no e'' such that $<e,e''>\in \|\|S\|\|\}$
4a.	$\|\|S_1\&S_2\|\| = \{<e,e'>\mid$ there is an e'' such that $<e,e''>\in \|\|S_1\|\|$ and $<e'',e'>\in \|\|S_2\|\|\}$ (= $\|\|S_1;S_2\|\|$)
4b.	$\|\|S_1vS_2\|\| = \{<e,e'>\mid$ e=e' and there is an e'' such that $<e,e''>\in \|\|S_1\|\|$ or $<e,e''>\in \|\|S_2\|\|\}$

An indefinite NP *a P* is taken to express an epsilon-update, i.e. its function is taken to be the updating of the actual epsilon function e to a new epsilon function e'. e' then differs from e at most in the representative of the set of P; the NP refers to this representative. We write $e^{||P||}$ for an e' resulting from the evaluation of *a P* with the input e. A definite NP *the P* denotes the representative of the set of P's according to the current epsilon function; it is taken to express the trivial epsilon-update. Further, it is required that there be at least one P — this expresses the existential presupposition of definite NPs. There is no uniqueness condition, since it is replaced by the condition that there exists the representative of the set of P's. A pronoun is defined to be semantically equivalent to the impoverished definite NP expressing merely the corresponding gender.

The atomic sentence is semantically characterized in 2 via its potential to change the current epsilon function e to the updated function e' by way of the subsequent application of the updates expressed by its terms. Thus, e and e' must be connected by a sequence of epsilon functions such that the adjacent pairs of the sequence fall into the respective updates expressed by the terms; and the referents of the terms must fall into the extension of the predicate. Here we differ essentially from usual dynamic logic in that we consider atomic sentences as internally and externally dynamic. The logical operators ¬ and v are static (they act as tests); they are in fact the classical operators only formally dynamized. & is the dynamic conjunction suitable for conjoining subsequent sentences.

I will illustrate this mechanism by analysizing a simple atomic sentence with an indefinite NP. Sentence (7) is assigned the formula (7a); this formula is then interpreted as (7b) according to the definitions given above. As we have noted, a pair of epsilons $\langle e,e'\rangle$ falls into the update expressed by an atomic sentence iff e and e' are connected by a sequence of epsilons such that the adjacent pairs of the sequence fall into the respective updates expressed by the terms and the referents of the terms fall into the extension of the predicate. Since we have only one term in (7), this reduces to the condition that $\langle e,e'\rangle$ falls into the update expressed by *a(man)* and that the referent of *a(man)* falls into the extension of walk. This yields $e'=e^{||man||}$ and $e'(||man||)\in||walk||$. The resulting set of pairs is clearly non-empty just in case $\exists d.d\in||man||\&d\in||walk||$ (i.e. if the intersection of ||man|| and ||walk|| is nonempty); and our formula (7b) is thus in this sense equivalent to the classical formula $\exists x(man(x)\&walk(x))$.

(7) A man walks

(7a) walk(a(man))

(7b) $||walk(a(man))|| = \{\langle e,e'\rangle | \langle e,e'\rangle\in||a(man)|| \text{ and } ||a(man)||_{e'}\in||walk||\}$

$= \{\langle e,e'\rangle | e'=e^{||man||} \text{ and } e'(||man||)\in||walk||\}$

Sentence (8) with the definite NP *the man* is represented and interpreted similarly to (7). The only difference is the condition on the epsilon function - the interpretation of the definite NP is static. The only condition is that the referent of the NP, determined by the current epsilon function, falls within the extension of the predicate. The difference between the definite and the indefinite NP thus lies in their different behaviors with respect to the epsilon function — the indefinite NP updates it, whereas the definite NP acts merely as a test. In both cases, the referent of the NP is yielded by the actual epsilon function.

(8) The man whistles

(8a) whistle(the(man))

(8b) ||whistle(the(man))||

$= \{\langle e,e'\rangle \mid \langle e,e'\rangle \in \|the(man)\| \text{ and } \|the(man)\|_{e'} \in \|whistle\|\}$

$= \{\langle e,e'\rangle \mid e=e' \ \& \ e'(\|man\|) \in \|whistle\|\}$

The analysis of the conjunction (9) of (7) and (8) shows how the referent of the anaphorical NP *the man* gets identified with that of its antecedent *a man*.

(9) A man walks. And the man whistles

(9a) walk(a(man))&whistle(the(man))

(9b) ||walk(a(man))&whistle(the(man))||

$= \{\langle e,e'\rangle \mid \text{there is an } e'' \text{ such that } \langle e,e''\rangle \in \|walk(a(man))\| \text{ and } \langle e'',e'\rangle \in \|whistle(the(man))\|\}$

$= \{\langle e,e'\rangle \mid \text{there is an } e'' \text{ such that } \langle e,e''\rangle \in \{\langle e,e'\rangle \mid e'=e^{\|man\|} \text{ and } e'(\|man\|) \in \|walk\|\} \text{ and } \langle e'',e'\rangle \in \{\langle e,e'\rangle \mid e=e' \text{ and } e'(\|man\|) \in \|whistle\|\}\}$

$= \{\langle e,e'\rangle \mid \text{there is an } e'' \text{ such that } e''=e^{\|man\|} \text{ and } e''(\|man\|) \in \|walk\| \text{ and } e''=e' \text{ and } e'(\|man\|) \in \|whistle\|\}$

$= \{\langle e,e'\rangle \mid e'=e^{\|man\|} \text{ and } e'(\|man\|) \in \|walk\| \text{ and } e'(\|man\|) \in \|whistle\|\}$

$\langle e,e'\rangle$ falls into the update expressed by (9b) if and only if there is an epsilon function e'' such that $\langle e,e''\rangle$ falls into the update expressed by (7b) and $\langle e'',e'\rangle$ falls into the update expressed by (8b). Using the results of the above analyses and eliminating redundancies, we reach the result that $\langle e,e'\rangle$ falls into the update expressed by (9b) iff e' differs from e at most in the representative of the class of men and this representative is a walker and a whistler.

Using this formalism, we can give a first analysis of the variety of anaphorical relations in (1a-f). The meaning of the first sentence in (1a) - (1f) consists of the pairs of choice functions e and e' such that e' is like e with the single possible exception that e' chooses a new representative for the class of farmers. Furthermore, the chosen representative must be in the extension of the predicate *walk*. The definite expression *the farmer* in (1c) then refers to this chosen representative. Thus, the anaphorical relation is not explained in terms of binding or by means of a Russellian description, but rather in the interaction of the context change potential of the antecedent together with the context dependent interpretation of the anaphorical term. However, this basic picture can only explain the definite NP in (1b) and (1c).

In order to account for the variants (1a), (1d) and (1e), Peregrin & von Heusinger (1995) modify the formalism by assuming that the indefinite NP *a farmer* does not only change the representative of the class of farmers, but also the representative of (certain) supersets, like the set of men or that of all (male) objects. Hence, the anaphorical expressions *the man* or *he* (as short for *the (male) object*) can refer back to the mentioned representative. Still, this modification does not explain the anaphorical link in (1f). An even more flexible account of salience change potential is neccessary.

6. The Salience Change Potential of Predicates

In order to account for anaphorical linkages, like in (1f), the salience change potential of the matrix predicate must be calculated, too. In the following, I confine the discussion to one place predicates. The interpretation 2 in Def.4c of the atomic sentence is modified as 2*. An atomic sentence of the schema *an F is G* induces a contextual change that consists in changing the representatives for the following sets: the set denoted by the head noun F, the set denoted by the predicate G, their supersets and their intersections. The object that is introduced by the indefinite NP *an F* becomes the new representative of the mentioned sets. The updated choice function e' can informally be represented as $e^{\|F\|\ \|G\|\ \|F\cap G\|\ \|U\cap G\|}$ indicating some of the modifications.

2.* ||G(a(F))|| ={<e, e'> | there is an individual d such that e'(s) = d iff
s is ||F|| or s is ||G|| or s is a superset of ||F|| or s is the intersection
of ||F|| or its superset with ||G||; and e'(s)=e(s) for all other sets s}

In this modified formalism, we can uniformly describe the anaphorical relations in (1a-f), reducing the different groups (i)-(iv) to the salience change potential of the expression involved. The first sentence, repeated as (10), updates a choice function e to $e^{\|\text{farmer}\|\ \|\text{walks}\|\ \|\text{farmer who walks}\|\ \|\text{thing that walks}\|}$. I.e., the update differs from the input for the representatives of the set of farmers, the set of walkers, their supersets and their intersections. This updated choice function is the input for the second conjunct in (1b) and (1f), repeated as (11) and (12). The definite expressions *the walking farmer* and *the walker* are interpreted according to the input choice function, and they refer to the same object that was named by the indefinite NP *a farmer* in the first conjunct.

(10) A farmer walks.

(10a) walk(a(farmer))|| ={<e, e'> | there is an individual d such that e'(s)= d iff s is ||farmer|| or s is ||walk|| or s is a superset of ||farmer|| or s is the intersection of ||farmer|| with ||walk|| or its supersets with ||walk||; and e'(s)=e(s) for all other sets s}

(11) A farmer walks. *The walking farmer* whistles.

(11a) {<e, e'> | there is an e" such that <e, e"> ∈ ||walk(a(farmer))| and <e", e'>∈ ||whistle(the(walking farmer))||} =
{<e, e'> | there is an e"= $e^{||farmer||\ ||walks||\ ||farmer\ who\ walks||\ ||thing\ that\ walks||}$
such that <e", e'>∈ ||whistle(the(walking farmer))||} =
{<e, e'> | there is an e"= $e^{||farmer||\ ||walks||\ ||farmer\ who\ walks||\ ||thing\ that\ walks||}$
such that e"(||walking farmer||)∈ ||whistle||}

(12) A farmer walks. *The walker* whistles.

(12a) {<e, e'> | there is an e" such that <e, e"> ∈ ||walk(a(farmer))| and <e", e'>∈ ||whistle(the(walker))||} =
{<e, e'> | there is an e" = $e^{||farmer||\ ||walks||\ ||farmer\ who\ walks||\ ||thing\ that\ walks|}$
such that <e", e'>∈ ||whistle(the(walking farmer))||} =
{<e, e'> | there is an e" = $e^{||farmer||\ ||walks||\ ||farmer\ who\ walks||\ ||thing\ that\ walks|}$
such that e"(||walk||) ∈ ||whistle||}

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