Grounding Dynamic Semantics

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"Wenn jemand heute dasselbe sagen will,
was er gestern das Wort 'heute' gebrauchend ausgedrückt hat,
so wird er dieses Wort durch 'gestern' ersetzen."
(Frege 1918, p. 64)

Abstract
In this paper we present and motivate a formal elaboration of the treatment of anaphoric relationships suggested in (Stalnaker 1998) which is close in spirit and scope to that of (Heim 1982; Groenendijk and Stokhof 1991). We agree with Stalnaker that an adequate account of the relevant facts does not require a dynamic semantic notion of meaning. Yet, we think, the data do provide motivation for such systems of dynamic interpretation.

A systematic treatment of anaphoric relationships along the lines suggested by Stalnaker requires us to take into account the referential intentions which can be associated with the use of (definite and indefinite) terms, as well as the dynamics of the speech act assertion. The dynamics of interpretation then can be seen to reside in a dynamic notion of conjunction, which is a form of intersection, basically, but infected by the generally available pragmatic information that in most conjunctions actually used, one conjunct literally precedes the other.

1 Assertions in Contexts

The treatment of structural semantic relationships in discourse has given rise to several, sometimes deemed major, deviations from classical semantic paradigms, as it has raised systems like discourse representation theory and dynamic semantics, among many others. However, in (Stalnaker 1998) it is argued that the phenomena, in particular inter-sentential anaphoric relationships, are not inconsistent with a classical conception of meaning, if only one pays due attention to the pragmatics of interpretation.

In this paper we elaborate Stalnaker's view on the issue, and argue that, although indeed a systematic account of the facts along the lines suggested does not presuppose a dynamic conception of meaning, it does motivate a dynamic notion of conjunction. We present a formal interpretation of a language of first order logic which can be seen to model the compositional interpretation of anaphoric relationships between indefinite noun phrases and anaphoric

pronouns in natural language. The semantics is spelled out as a classical satisfaction relation, which is extended so as to account for two, arguably systematic, pragmatic principles. Firstly, it pays due attention to the fact that indefinite noun phrases are generally used with referential intentions and therefore enable subsequent anaphoric coreference.[1] Secondly, it takes the fact to heart that in the conjunction of two assertions, one literally precede the other.

We want to show that by taking these two pragmatic principles to heart, we have a convenient handle on the data, and we, thus, hope to reconcile the linguistics and philosophy of anaphoric binding. The empirically promising theories of anaphora which have emerged from the discourse representation and dynamic paradigms, can be coherently conceived of as naturally emerging from a philosophically motivated, standard, formal notion of meaning.

Surprisingly, it appears that it is not so much the dynamics of (existential) quantification and conjunction that stands in need of explanation, but, rather, the blocking effects which other connectives and quantifiers are generally assumed to have upon this. In the final section of this paper we therefore offer a preliminary explanation of these blocking effects, this, again, in terms of pragmatic principles governing information exchange. We start, however, with an overview of some points made in (Stalnaker 1978; Stalnaker 1998).

In his pioneering (Stalnaker 1978), Stalnaker points out that the interpretation of indicative sentences may crucially rely upon pragmatic facts related to their use. In order to see what proposition is expressed by means of an utterance of "You could be a mega-star," we have to know the identity of the addressee of the utterance. The content of the utterance, thus, depends on a non-linguistic (non-syntactic and non-semantic) fact, one which we dub a 'pragmatic fact' in the sequel.[2]

Pragmatic facts affect interpretation in more than one way. When someone makes an assertion, and no interfering conditions hamper communication, it is normally assumed that the interlocutors acknowledge that the assertion has been made, and that they accept the assertion if they do not explicitly indicate disagreement with its contents.[3] If this is indeed a systematic fact about the use of indicative sentences in our culture, then other utterances may rely on it. For instance, if we abuse a worn-out example, we can imagine that someone says:

(1) France has one and only one king.

and, if nobody objects, that she continues with:

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1. Notice that we are *not* claiming that the terms themselves are referential.
2. Referring, exclusively, to the established linguistic trichotomy between syntax, semantics and pragmatics.
3. This is a vast simplification of what ordinarily goes on in actual situations of information exchange, and it also neglects differences in the culture of the relevant information society. In some (sub-)cultures, what certain persons say is accepted by rule; in other (sub-)cultures, this depends on the absence of explicit disagreement of the interlocutors; in yet other (sub-)cultures, acceptance requires explicit agreement among all parties.

(2) And the king of France has dreadlocks.

Linguistic agents may object to this sequence of utterances for various reasons. Semantic reasons include that, e.g., France does not have one and only one king, or that, if France has one, the king of France is bald. But it seems that it is inappropriate to admit the utterance of (1), and then to say that the subsequent utterance of (2) is pragmatically deviant, because France does not have a (unique) king. The utterance of (1), and the subsequent absence of protest, thus precludes a rejection of (2) on grounds of presupposition failure.

It is a platitude that things change when people do something, but things also may change when people do nothing. If agents carry out an action, and also if they refrain from doing so, the world changes: after the action, the action has been carried out, and the effects are probably notable; but also if no action has been carried out, then the world follows its scheduled course of events and afterwards it is true that the action has not been carried out. In general, we may assume that after an assertion has been made, and not before, it is true that that assertion has been made and that after no objection has been made, it is true that the content of the assertion is accepted, for the time being at least.

The preceding observations we consciously deem to be platitudes, be it platitudes which may have non-trivial implications for the theory of interpretation. For systems of discourse representation theory and dynamics semantics, which arguably focus on the systematic effects which certain utterances may have on the current state of a dialogue, the implications of this have been taken to be far-reaching. Hans Kamp, for instance, has taken them to support a non-compositional semantics,[4] and Groenendijk, Stokhof and Veltman have taken them to motivate a dynamic semantic notion of meaning.[5] In either case the analysis of the dynamics of discourse has been seen to imply a significant departure from the received semantic paradigms, in which meaning is spelled in terms of truth- or satisfaction-conditions.

In what follows we take our cue from (Stalnaker 1998) and argue that, eventually, such radical shifts of our concept of meaning are not at all required to account for the data which the mentioned theories set out to give an account of in the first place—anaphoric relations in discourse.[6] However, we will only follow Stalnaker in maintaining that the data are consistent with a classical outlook upon meaning, like the one presupposed in, e.g., (Stalnaker 1978). In opposition to Stalnaker, however, we argue that a fair and systematic account of the data does require some dynamic notion of interpretation and that discourse representation theory and dynamic semantics can be said to offer just this. Frameworks like these two arguably offer a systematic elaboration of the analy-

4. It must be admitted that these claims are not attested any longer.
5. Although it seems such has never been said so explicitly in print.
6. Thus, this paper says nothing about other issues people might bring up in favour of a representational or dynamic theory of meaning.

sis of anaphoric relations suggested by Stalnaker himself. We will show this by presenting a toy system of interpretation (predicate logic with anaphora, *PLA*), which gives a truly dynamic account of the facts about anaphoric relationships on the basis of a static, classical, notion of meaning. We present intuitive, semantic and pragmatic motivation for all features of this system, including both its dynamic notion of conjunction and its static notion of negation.

2 Indefinites and Anaphoric Pronouns

Let us first inspect some of the relevant data. Suppose someone (Liz) says at some time t:

(3) A magistrate from Gotham city yesterday confessed having blackmailed young women.

Various, more and less trivial, observations can be made about such an assertion. In the first place, Liz has produced certain sounds at t, most probably a string of English words, together making up a sentence. Assuming this to be indeed the case, we can also observe that a substring consisting of the first five words constitutes an indefinite noun phrase. So it also holds true that Liz uttered an indefinite noun phrase at t. Other facts about the utterance are of a semantic and pragmatic nature, for instance facts about the truth or truth-conditions of the utterance, and facts about its felicity.

Our interest here is mainly in semantic/pragmatic facts about the indefinite noun phrase "A magistrate from Gotham city." It may first be observed that the utterance says nothing about the identity of the magistrate. For the utterance to be true, there must be some magistrate from Gotham city who made such a confession, but for as far as we know this can be any magistrate, and it may concern different magistrates in different contexts of evaluation. However, it is often assumed or argued, that indefinites are generally used with what we call referential intentions.[7] Thus, where we just now (5 lines above this one) talked about "the identity of the magistrate," we were really supposing that Liz, in the hypothetical situation, would have referred or would have intended to refer to a certain individual.

Let us inspect this notion of a referential intention in a little more detail. Firstly, it seems obvious to us that Liz' utterance by itself does not enable anyone to identify an intended referent. Secondly, even the speaker (Liz) may fail to know, in a certain sense, whom she is referring to.[8] For she just might have heard, herself, what she reported with her utterance of (3), or she might

7. Related ideas can be found in the more classical and philosophically oriented literature such as, e.g., (Chastain 1975; Donnellan 1978; Kripke 1979; Evans 1982). More recent, and, arguably, more linguistically oriented motivation can be found in (Kadmon 1987; Kamp 1990; van Rooy 1997; Zimmermann 1999; Dekker 2002).

8. That is, if her interlocutor asks which magistrate she is talking about, she may reply "I don't have the faintest idea," without this disqualifying her as a cooperative speaker.

have read it in the tabloids. Nevertheless, thirdly, we think this still does not preclude that Liz used the indefinite with referential intentions. For her it may very well be the individual, whoever it is, that she was told about when she was told what she now reports with (3), or, alternatively the individual, whoever it is, which she read about in the tabloids.[9] Fourthly, and finally, we take it that the intended reference is of a pragmatic nature and not a semantic one.

Although the intended reference of an indefinite description is qualified as a pragmatic affair, it may have a semantic role to play. Like we said above, a pragmatic fact about an utterance situation may determine the semantic reference of a personal pronoun like "you" or "I", and, likewise, the intended referents of indefinite noun phrases may constitute the referents of subsequent anaphoric pronouns. Thus, after uttering (3), Liz might continue with (4):

(4) He had found out they had been bewitching cows before.

In the described situation, the pronoun can be taken to refer to whoever was the intended referent of the preceding indefinite. That is, the interpretation of a pronoun may draw from a fact about the utterance situation, that it is used in a context where just before an indefinite noun phrase has been used, and be interpreted as referring to the intended referent of precisely that noun phrase.[10] So, as Stalnaker himself observes, an account of anaphoric relationships between indefinite noun phrases and pronouns doesn't seem to require anything beyond a truth-conditional notion of meaning, if we pay due attention to the pragmatic principles governing the use of indefinite noun phrases and pronouns. Meaning and pragmatics together suffice to give a characterization of the content of utterances like that of (3–4). However, unlike Stalnaker, it seems, we don't think these observations constitute any evidence against systems of dynamic interpretation, or point at any (conceptual) redundancy of these. For it is one thing to observe that meaning and pragmatics might, in principle, be able to account for a set of data; it is another one to actually provide that account.

Consider again the sequence of utterances (3–4). For a characterization of the content of the two utterances, one will have to take into account the fact that after Liz's utterance of (3), and not before, an indefinite noun phrase has been used, and that, this explains why the pronoun in (4) can be resolved. (It literally has an *ante*cedent. Notice that this would not be true if example (4) was uttered before (3) and that that order of utterances, out of the blue, would sound odd.) It thus appears that the temporal order of utterances is relevant to interpretation, and also that this appears to be quite a systematic fact.[11]

So, also if we submit that a dynamic notion of *meaning* need not be

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9. Surely, anyone who would accept what Liz has said with (3) may report the same thing with the intention to refer to the individual which Liz intended to refer to when uttering (3).
10. Thus, the situation is entirely similar to the ones involving definite descriptions, as they are discussed in (Donnellan 1978; Kripke 1979).
11. Anaphora is a much more widespread phenomenon than the relatively marginal phenomenon of kataphora.

called for, still, if we are after a systematic account of the relevant facts of *interpretation*, we are bound to acknowledge these aspects of interpretation, which may very well be called dynamic. And as a matter of fact, one can as well hold that what systems of dynamic semantics provide is precisely such an account. In order to account for anaphoric relationships in discourse, we somehow have to get a hold on the fact that the use of, e.g., indefinite noun phrases induces a change in the facts relevant to the interpretation of (subsequent) pronouns. Systems of discourse representation and dynamic semantics can be seen to present two of the many possible means of coming to grips with these pragmatic facts in a systematic fashion.

In order to substantiate the last points, we set out, in the next section, to present an, admittedly stylized, analysis of anaphoric relations which we claim to be fully in line with all of Stalnaker's observations. The proposed analysis is based upon a classical notion of meaning, which is enriched just in order to accommodate the pragmatic observations above. We submit that, as the reader will see, this is somewhat of a formal exercise, but it does help to clarify two points. First, it serves to substantiate Stalnaker's own point that the relevant data are not at odds with a classical notion of meaning. Secondly, however, it also serves to bring out what the dynamics of interpretation actually consists in. In section 4 and 5 we will argue in further detail that each of the clauses making up our, arguably dynamic, system of interpretation indeed are given in by independently motivated semantic and pragmatic principles.

In the remainder of this section we sketch how we plan to carry out a Stalnakerian analysis of simple anaphoric relationships. We substantially simplify matters by only looking at possible anaphoric relationships between indefinite noun phrases and anaphoric pronouns, and we furthermore assume that:

1. surface indefinite noun phrases are generally used with referential intentions;[12]
2. anaphoric pronouns pick up possibly intended referents of preceding indefinites;[13]
3. we can neglect information structure, so that the descriptions under which the possible referents of indefinites are introduced carry the same cognitive or communicative value as those next attributed to them.[14]

Like we said, although indefinite noun phrases and pronouns are used with referential intentions, it is normally not clear from their semantics alone which individuals, if any, as a matter of fact satisfy these intentions. Their informa-

12. Non-surface indefinite noun phrases are not generally associated with referential intentions. In various contexts these intentions are blocked, for instance in the context of a negation, of a question, or in the clauses making up the restriction of quantifiers. We will come back to this point below.

13. It is only for ease of exposition not to include other possible antecedents.

14. This is not simply a technical simplification, but one which has to be given up in due course. From the formal, systematic, perspective which we adopt in this paper, however, this is only a technical one.

tional contribution is therefore conceived of as functional upon their possible referents. Thus, the referential intentions associated with the use of indefinite noun phrases are modeled, below, in terms of their possible referents. And since, in a piece of discourse, the various indefinites come in a particular order, the whole sum of referential intentions are modeled by means of sequences of possible referents, that is, by means of sequences of individuals that are possible referents of the indefinites in the discourse. As we will see below it turns out to be convenient to model these sequences in reversed order, so that a sequence $d_1, d_2, \ldots$ is said to satisfy a certain discourse, if d_1 is a possible referent of the indefinite used *last*, d_2 of the indefinite used *one but last*, etc.[15]

The above assumptions are made explicit in our statement of the interpretation of a simple language of first order logic, in which existentially quantified formulas model the interpretation of indefinite noun phrases and in which an additional category of anaphoric pronouns $(\mathtt{p}_1, \mathtt{p}_2, \ldots)$ pick up the possible referents of preceding indefinites. Pronouns are assumed to look back in the discourse for preceding antecedents. More particularly, a pronoun $\mathtt{p}_i$ is interpreted so that it requires there to be at least i preceding antecedents, and when this requirement is met it is coreferential with the i-th indefinite found when going back in the discourse from the place where the pronoun occurs. Pronouns, thus, are truly indexical.[16]

3 Predicate Logic with Anaphora

The system of interpretation which we present in this section is referred to as *PLA*, *(Static) Predicate Logic with Anaphora*.[17] The language of *PLA* is like that of first order predicate logic except for the fact that it also contains a category of pronouns $P = \{\mathtt{p}_1, \mathtt{p}_2, \ldots\}$. For ease of exposition, we focus on a minimal language, without names and identity, and which is built up from variables, pronouns, and n-ary relation expressions, by means of negation $\neg$, existential quantification $\exists x$ and conjunction $\wedge$. As is usual, we use existentially quantified expressions to model indefinite noun phrases. Conditional sentences can be modeled using implication $\rightarrow$, defined by $(\phi \rightarrow \psi) \equiv \neg(\phi \wedge \neg\psi)$.

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15. The relevant order of indefinites does not always correspond to their linear surface order though. It is determined by syntactic structure, and an indefinite in the scope of another indefinite is taken to precede it. In formal terms, $\exists y$ comes before $\exists x$ in $\exists x(\ldots \exists y(\ldots))$, although, of course, it comes after $\exists x$ in $\exists x(\ldots) \wedge \exists y(\ldots)$.

16. And we have to add that, for expository reasons, we have stated an extensional account. In order to account for anaphoric relationships in case there are no possible referents in the actual world, we have to resort an intensional model. Such a generalization is pretty straightforward, though, cf., (Dekker 2002).

17. In an earlier paper (Dekker 1994) a closely related system was presented as an update semantics. Although the system in that paper was called *Predicate Logic with Anaphora* as well, we prefer to call the system presented here *PLA*, and refer to the system in (Dekker 1994) as *DPLA*, *Dynamic Predicate Logic with Anaphora*.

Before we turn to the semantics of *PLA*, we first have to define what we call the 'length' of a sentence, the number of existentials in it which are or can be used with referential intentions.[18] Within the formal system of *PLA* the length $n(\phi)$ of a formula ϕ corresponds to the number of existential quantifiers not in the scope of a negation:

(5) $n(Rt_1 \ldots t_m) = 0 \qquad n(\exists x\phi) \quad = n(\phi) + 1$
$n(\neg\phi) \qquad = 0 \qquad n(\phi \wedge \psi) = n(\phi) + n(\psi)$

Since we only count the contribution made by indefinite noun phrases in this paper (cf., the assumptions at the end of the previous section), only the corresponding existentials are taken to contribute an element. The length of $\exists x\phi$ thus is that of ϕ plus one. Obviously, the number of existentials in a conjunction has to be the sum of the numbers of existentials in the two conjuncts. And, like we said, negations are assumed to block referential intentions, and, hence, anaphoric potential, so that $n(\neg\phi) = 0$.[19]

Using the notion of $n(\phi)$ we can already explain how anaphoric pronouns are going to be resolved. Like we said, a pronoun $\mathbf{p}_i$ is indexically analyzed, in that it refers back to the i-th indefinite noun phrase which it finds if it looks back in the discourse from the location where the pronoun occurs. Thus, if an atomic formula ψ with a pronoun $\mathbf{p}_i$ is conjoined with a preceding formula ϕ, and if $i \leq n(\phi)$, then the pronoun is coreferential with a term in ϕ (viz., the $n(\phi) - i$-th one), and the pronoun is called 'resolved' in the conjunction $\phi \wedge \psi$. If, on the other hand, $n(\phi) < i$, then the pronoun is not resolved, and it will be taken to refer back to the $(i - n(\phi))$-th potential antecedent before the conjunction $\phi \wedge \psi$. Furthermore, a pronoun cannot be resolved by a quantifier that has the pronoun in its syntactic scope. So if a pronoun in a formula ψ presuppose j antecedent existentials before ψ, then it will also presuppose j antecedents before $\exists x\phi$ (and before $\neg\phi$, for that matter).

We now turn to the semantics of *PLA* itself. The semantics of *PLA* is specified, basically, as a Tarskian satisfaction relation between sequences of individuals and formulas.[20] This relation holds of a sequence and a formula if the formula is judged true when its open places (existential and pronominal) are filled with the corresponding individuals in the sequence. Notice that such sequences this time do not determine the values of the free variables of a formula, as in, e.g., (Tarski 1956).[21]

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18. The fact that a sentence or discourse has length n can be conceived of as a 'fact about the discourse' or 'discourse information'. Although this type of information is not part of the *content* of a discourse, it is relevant for the *determination of its content*, i.e., for its interpretation. (Cf., also Groenendijk et al. 1996; Stalnaker 1998).

19. Notice that this is the default option chosen in systems of discourse representation and dynamic semantics. Cf., section 5 for more discussion.

20. It is notationally convenient to assume these to be infinite sequences, although nothing hinges upon this assumption.

21. Variables and variable binding are dealt with by means of variable assignments. The open places which we are concerned with here are those corresponding to indefinite noun phrases

The *PLA*-interpretation of terms is defined relative to a variable assignment and a sequence of individuals. Variables are assigned the value which the current variable assignment assigns to them, and a pronoun $\mathbf{p}_i$ selects the i-th individual from the sequence, thus indicating that it is coreferential with the i-th potential antecedent in preceding discourse:[22]

(6) $[x]_{g,\vec{e}} = g(x) \qquad [\mathbf{p}_i]_{g,\vec{e}} = \vec{e}_i$

Satisfaction is defined relative to a first order model M, a variable assignment g and a sequence of individuals $\vec{e}$. A model $M = \langle D, E\rangle$ consists of a domain of individuals D and an interpretation E for the non-logical constants. If a sequence $\vec{e}$ satisfies a formula relative to a model M and an assignment g we will write $\vec{e} \models_{M,g} \phi$. Satisfaction is defined as follows:

(7) $\vec{e} \models_{M,g} Rt_1 \ldots t_m$ iff $\langle [t_1]_{g,\vec{e}}, \ldots, [t_m]_{g,\vec{e}}\rangle \in E(R)$
$\vec{e} \models_{M,g} \exists x\phi$ iff $\vec{e}{-}1 \models_{M,g[x/\vec{e}_1]} \phi$
$\vec{e} \models_{M,g} \neg\phi$ iff $\neg\exists \vec{c} \in D^{n(\phi)}$: $\vec{ce} \models_{M,g} \phi$
$\vec{e} \models_{M,g} \phi \wedge \psi$ iff $\vec{e}{-}n(\psi) \models_{M,g} \phi$ and $\vec{e} \models_{M,g} \psi$
where $\vec{e}{-}m$ is the sequence $\vec{e}_{m+1}, \vec{e}_{m+2}, \ldots$

(8) ϕ is true wrt M, g and $\vec{e}$ iff $\exists \vec{c} \in D^{n(\phi)}$: $\vec{ce} \models_{M,g} \phi$

Given a model-theoretic interpretation of relational constants, atomic formulas are evaluated relative to variable assignments, as in ordinary predicate logic, and relative to sequences of individuals, as in, e.g., (Tarski 1956). Any pronoun $\mathbf{p}_i$ in such a formula puts constraints on the i-th individual in such a sequence, and—by our dynamic notion of conjunction—this implies that it puts constraints on the possible referent of the i-last existential.

An existentially quantified formula $\exists x\phi$ behaves like an ordinary quantifier as it governs free occurrences of the variable x in its scope. However, it also behaves like a free variable itself. Possible witnesses for the quantified statement come from the first individual in the sequence relative to which the quantified formula is evaluated. So if $\vec{e}$ is a sequence satisfying ϕ under an assignment of d to x, then $d\vec{e}$ satisfies $\exists x\phi$. It is precisely because these sequences thus keep track of the possible witnesses d of x, that they can be (re-)addressed by subsequent pronouns.[23]

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and anaphoric pronouns.

22. If $\vec{e}$ is a sequence of individuals $d_1, d_2, \ldots$, then $\vec{e}_i$ is d_i.

23. In the, arguably somewhat scholastic, literature on indefinites the Lewis/Kamp/Heim approach has been characterized as one offering an outlook upon indefinites as free variables, whereas the dynamic approaches of, e.g., Barwise and Groenendijk and Stokhof stick to the analysis of indefinites as (existentially) bound variables. This picture has to be adjusted significantly. On the one hand the Lewis/Kamp/Heim approach favors an (existential) closure of all indefinites at some level of analysis. On the other, existentially bound variables in systems of dynamic semantics are still free in some sense. As I have shown in (Dekker 1993), such dynamic existentially bound variables can be (re-)bound by other quantifiers using a technique called 'existential disclosure'. For the interested reader: if x is bound by a dynamic existential quantifier in ψ, then it turns out to be universally quantified in $\forall y(\psi \wedge x = y)$. Thus, if $\psi \equiv \exists x Fx$, then $\forall y(\psi \wedge x = y)$ is (fully) equivalent to $\forall y Fy$.

The negation of a formula ϕ tells us that ϕ is simply false. It states that there is no way to fill ϕ's open places with a sequence $\vec{c}$ of $n(\phi)$ individuals. A negation thus closes the 'existential holes' of the formula ϕ in its scope, so that, e.g., $\neg\exists x Fx$, as usual, means that no x is F. As a consequence, existential quantifiers (corresponding to indefinites) in ϕ cannot serve as antecedents for subsequent pronouns.

If we evaluate a conjunction $\phi \wedge \psi$ relative to a sequence $\vec{e}$, we evaluate the first conjunct ϕ relative to $\vec{e}$–$n(\psi)$, which is $\vec{e}$ with the contribution of ψ stripped of. Intuitively, this says that ϕ is evaluated *before* ψ has contributed its discourse referents. Probably it is easier to read it in a constructive way. If $\vec{e}$ satisfies ϕ, and $\vec{c}\vec{e}$ satisfies ψ, where $\vec{c}$ fits the indefinites contributed by ψ, so that the length of $\vec{c}$ is $n(\phi)$, then $\vec{c}\vec{e}$ satisfies $\phi \wedge \psi$ as well. The reader may observe that this is a truly dynamic notion of conjunction. The dynamics resides in the fact that the interpretation of the first conjunct ϕ is updated. Sequences satisfying ϕ are updated with the information that $n(\psi)$ more terms have occurred when we evaluate ϕ's conjunction with ψ.

Let us briefly see how *PLA* handles key-note examples of systems of dynamic interpretation:

(9) A diver found a pearl. $[\exists x(Dx \wedge \exists y(Py \wedge Fxy))]$

The length of formula [9] is 2, and straightforward calculations show that:

(10) $cd\vec{e} \models_{M,g} [9]$ iff $c \in E(D)$, $d \in E(P)$ and $\langle c, d\rangle \in E(F)$

that is, if, and only if, c is a diver who found pearl d. Next consider:

(11) She sold it to a tourist. $[\exists z(Tz \wedge S\mathtt{p}_1\mathtt{p}_2 z)]$

The length of this formula is 1, but it imposes restrictions, not only on the first element which it mentions, but also on two preceding subjects. The formula is satisfied by a sequence $bcd\vec{e}$:

(12) $bcd\vec{e} \models_{M,g} [11]$ iff $b \in E(T)$ and $\langle c, d, b\rangle \in E(S)$

that is, if and only if b is a tourist which c sold d to. In the conjunction of [9] and [11], the two pronouns are resolved:

(13) A diver found a pearl. She sold it to a tourist. $[9 \wedge 11]$

The length of the conjunction is 3 and since it is resolved, it only places constraints on these first three elements of a satisfying sequence:

(14) $bcd\vec{e} \models_{M,g} [13]$ iff $cd\vec{e} \models_{M,g} [9]$ and $bcd\vec{e} \models_{M,g} [11]$ iff
c, a diver, sold d, a pearl c found, to tourist b

Since a speaker, by uttering (9), is assumed to refer to a diver and a pearl she found, the two subsequent pronouns can be identified with the possibly intended referents of the two terms. Thus, in particular, both sentences impose their own constraints on the second and third element of the sequences satisfying the conjunction.

Since pronouns may address existentials in precedent conjuncts, and since implication $(\phi \rightarrow \psi)$ is defined as $\neg(\phi \wedge \neg\psi)$ in terms of negation and

conjunction, pronouns in ψ may relate to existentials in ϕ. The semantic effect is the usual one in systems of dynamic semantics. For if we work through the definition of $\rightarrow$ we find that:

(15) $\vec{e} \models_{M,g} \phi \rightarrow \psi$ iff $\forall \vec{c} \in D^{n(\phi)}$: if $\vec{ce} \models_{M,g} \phi$ then $\exists \vec{a} \in D^{n(\psi)}$: $\vec{ace} \models_{M,g} \psi$

Thus, a worn-out example like the famous 'donkey-sentence':

(16) If a farmer owns a donkey he beats it.
$[\exists x(Fx \wedge \exists y(Dy \wedge Oxy)) \rightarrow B\mathbf{p}_1\mathbf{p}_2]$

turns out to be satisfied in *PLA* (by any sequence $\vec{e}$) provided that every farmer beats every donkey he owns:

(17) $\vec{e} \models_{M,g} [16a \rightarrow 16b]$ iff
$\forall cd \in D^2$: if $cd\vec{e} \models_{M,g} [16a]$ then $cd\vec{e} \models_{M,g} [16b]$ iff
$\forall cd \in D^2$: if $c \in E(F)$, $d \in E(D)$ and $\langle c, d\rangle \in E(O)$ then $\langle c, d\rangle \in E(B)$
i.e., iff $((E(F) \times E(D)) \cap E(O)) \subseteq E(B)$

Now we have defined and illustrated the system of *PLA*,[24] we may turn back to the issues discussed in the previous sections. What does this system teach us about the dynamics of interpreting (inter-sentential) anaphoric relationships?

4 Motivation for *PLA*

In the presentation and explanation of the *PLA*-interpretation procedure we have alluded, every now and then, to observations about the use of indefinites and pronouns in natural language interpretation. Earlier, in section 2, we claimed that the system of *PLA* fleshes out the type of observations or intuitions called upon by Stalnaker. So let us now try and see, in a systematic fashion, how much of the system is actually motivated by such intuitions. This section inspects the intuitions behind all but one of the clauses by means of which the semantics of *PLA* is spelled out, that is, the definition of the length of a formula and three of the four clauses defining the *PLA* satisfaction relation. Motivation for the clause dealing with negation is the subject of section 5.

First consider the length $n(\phi)$ of ϕ, the number of open existentials in a formula. As it is stated it is an entirely syntactic notion, which cannot (always) be derived from the set of sequences satisfying a formula. However, as we indicated, this notion should not be understood to characterize a syntactic property of formulas, but a pragmatic property of the use of these formulas. Properly conceived, $n(\phi)$ tells us that if someone has uttered a (sequence of) sentences corresponding to ϕ, then she has uttered $n(\phi)$ indefinites with referential intentions (cf. the assumptions made at the end of section 2). Thus we claim $n(\phi)$

24. The interested reader is referred to (Dekker 1994 and Dekker 2002, § 3) for a further exposition of this system, a normalization procedure and a systematic comparison with first order predicate logic.

to characterize a pragmatic fact about the utterance of sentences corresponding to ϕ, which we, like Stalnaker, take to be relevant for the interpretation of subsequent utterances. For each of these indefinites might have been used with referential intentions which steer the interpretation of subsequent pronouns.

Let us now take another look at the interpretation of terms, which are dealt with in the clauses defining the satisfaction of atomic and existentially quantified formulas. Satisfaction of an atomic formula At is defined in a standard way, except for the fact that the formula may house anaphoric pronouns, the interpretation of which is determined by satisfying sequences of individuals. As the system is set up, a pronoun $\mathbf{p}_i$ in At is coreferential with the i-th existential or indefinite used before At. We submit that this rigid use of indices is somewhat artificial, but actually it is nothing more than a technical simplification.[25] The rationale behind this interpretation of pronouns is like that indicated by Stalnaker. The pronoun is intended to refer to what can be called an 'intentionally present' individual.

Existentials are treated in the traditional fashion, except for the fact that a sequence that satisfies an existentially quantified formula is headed by a witness for the variable quantified over. As we already indicated above, this witness counts as a possibly intended referent, given that, as we assumed at the end of section 2, we do not distinguish between the descriptive material which a speaker uses to (indefinitely) refer to an individual on a certain occasion, and what she asserts of that individual on that occasion.[26] The analysis of existentials and pronouns thus is motivated by the idea that both types of terms can be used with referential intentions, even though the actual referents are not definitely determined. A sequence of individuals satisfies a formula if a corresponding sentence can be asserted with the successive individuals as the possible referents of the successive terms in that sentence.

Before we take a further look at the intuition behind the *PLA*-notion of conjunction, it may be emphasized that the semantics of *PLA* is stated in a static fashion. Sequences of individuals are employed as they are in Tarski's definition of the semantics of first order logic (Tarski 1956), the mere difference residing in the sort of terms which these sequences supply values for. In a Tarski-style semantics the sequences supply possible values of (sequences of) open positions which are eventually quantified; in our system they relate to the (sequences of) open positions induced by pronouns and indefinites. Technically, the difference is immaterial, while, pragmatically, it is given in by the kinds of intuitions put forward by Stalnaker.

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25. Notice that such a disambiguating simplification is adopted by virtually all formal systems of interpretation.

26. We thus neglect, deliberately, the interesting issues addressed in (Donnellan 1978; Kripke 1979), among others. Dropping the mentioned assumption is of course not impossible, but it would complicate matters more than needed for the purposes of this paper. Cf., e.g., (Dekker 2002) for some further discussion.

Although the *PLA* satisfaction relation can be conceived to be classical in nature, its system of interpretation nevertheless is dynamic, and this is due to its arguably dynamic notion of conjunction. The satisfaction of a conjunction $\phi \wedge \psi$ by a sequence $\vec{e}$ is stated in terms of the satisfaction of ψ by $\vec{e}$ and that of ϕ by $\vec{e} - n(\psi)$. This definition should be understood in the following manner. If a sequence $a\vec{c}e$ supplies the possibly intended referents $\vec{a}$ of ψ plus those $\vec{ce}$ that might have been introduced before ψ, and if $\vec{ce}$ supplies the possibly intended referents $\vec{c}$ of ϕ plus those $\vec{e}$ that might have been introduced before ϕ, then $a\vec{c}e$ supplies the possibly intended referents $\vec{ac}$ of $\phi \wedge \psi$ plus those $\vec{e}$ that might have been introduced before $\phi \wedge \psi$.

The *PLA*-notion of conjunction is meant to account for the fact that when we extend our evaluation of an utterance of ϕ with that of a subsequent utterance of ψ, we take into account that $n(\psi)$ more terms with referential intentions have been used after the conjunction of ϕ with ψ. The *PLA*-satisfaction of a conjunction $\phi \wedge \psi$ thus is stated in terms of the satisfaction of both ϕ and ψ, while it bears witness of the fact that satisfaction of ϕ is evaluated $n(\phi)$ terms before that of ψ is assessed. This notion of conjunction clearly shows the indexical nature of *PLA*'s system of interpretation. The satisfaction of $\phi \wedge \psi$ is stated in terms of the satisfaction of ψ, and the satisfaction of ϕ *before all of the indefinites of* ψ *have been used*, and this is why pronouns in ψ may pick up intended referents mentioned before. Thus conceived, all that is dynamic about the *PLA*-notion of conjunction—and, hence, about the *PLA*-notion of interpretation—is that it accounts for the intuition that in a succession of two assertions, one assertion literally precedes the other.[27]

So far, satisfaction of a *PLA*-formula ϕ can be seen to be defined as a classical satisfaction relation which is extended so as to accommodate certain pragmatic facts about the use of sentences corresponding to ϕ. In order to deal with the interpretation of anaphoric pronouns which can possibly be used later, the system of interpretation systematically takes into account what are possibly intended referents of the indefinites used, neatly (linearly) ordered following the order of occurrence of the indefinites at issue.

This leaves us with finding motivation for the last clause which we have not dealt with so far, the one concerned with negation. As we think this clause deserves special attention, in particular attention from a more general perspective, it is dealt with in a separate section.

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27. It is this intuition which we also read in Frege's 'donkey-imperative', which figures as a motto above this paper. If someone asserted "Es regnet heute" yesterday, and asserts "Es regnet heute nicht" today, then the conjunction of the two assertions today is given by the assertion that it rained *yesterday*, and that it doesn't rain today. The indexical proposition asserted yesterday has to be updated, today, with the pragmatic fact that it is one day later now.

5 On Blocked Referential Intentions

Under the Stalnakerian perspective which we have sought to elaborate in this paper, it doesn't seem to be a mystery any longer why indefinites and pronouns interact in the dynamic way they do. Like definite noun phrases, indefinites noun phrases can be used with referential intentions, and anaphoric pronouns simply pick up the referents intentionally related to their antecedents. However, another mystery now shows up its head: why do indefinites seem to stop behaving dynamically when they appear in the scope of a negation? Like we said, in *PLA*, as in most other systems of dynamic interpretation, the negation $\neg\phi$ of a formula ϕ disables pronominal coreference of subsequent pronouns with existentials in ϕ. Derived notions like that of implication, universal quantification etc., do likewise, as do modal constructions, questions, suppositions, and imperatives. From the pragmatic perspective advocated in this paper, this raises an intriguing question. If, as we think, anaphoric potential derives from referential intentions, then why do these referential intentions vanish in these negative (and other) contexts?[28]

We think the blocking effects of negations and other constructions can be understood well when we take into account their typical role in actual dialogues and the thematic structure of such dialogues. A negation *Not S* may serve to answer the issue—raised explicitly or implicitly—whether S is true. For instance, consider an utterance of (18):

(18) Farly doesn't run a sushi bar.

Typically, such an utterance does not serve to state of Farly and of some sushi bar that the first doesn't run the last. It is much more likely that such an utterance serves to state—possibly in answer to the question whether Farly runs a sushi bar—that he doesn't, that is, that there is no such bar which Farly runs.[29] Generally, then, a speaker need not have a particular sushi bar in mind when uttering (18), and the reason may be that, intuitively, the existence of such a sushi bar is not part of what the speaker claims to have evidence for. Rather, the existence of such a bar appears to be part of the issue which the speaker addresses—negatively in example (18)—, or even part of what the hearer might have claimed just before. So actually, when somebody utters (18), she is normally not coming up with a sushi bar herself, but she is claiming to have evidence against the existence of such a bar, were anybody else thinking of

28. Surely this 'generalization' requires some qualification. Indefinite noun phrases can be used 'specifically' in all of the mentioned contexts—under a negation, in the restriction or scope of adnominal and adverbial quantifiers, etc. However, we think that the usual interpretation of indefinites in these contexts is not 'specific' in this sense. Since our aim is to understand the more systematic patterns of interpretation in the first place, we would like to understand why indefinites in these contexts generally fail the anaphoric potential which they normally have outside of them.

29. One has to be careful with this kind of qualifications, because alternative interpretations are easily made available by emphasizing, e.g., *Farly*, or *run*. We here assume the utterance to carry what may be called a 'neutral' intonation.

the possibility of there being one, or even of thinking of claiming there actually to be one.[30]

Our sketch of the pragmatics of negation is reminiscent of the one adopted in systems of game-theoretical semantics (*GTS*, cf., e.g., Hintikka and Sandu 1997 for a recent overview). Borrowing *GTS*-terminology, negation can be considered a 'role switching' device. In *GTS*, the truth of ϕ is defined in terms of the existence of a winning strategy for a 'verifier'. A verifier is supposed to come up with evidence for ϕ and be able to supply witnesses for (indefinite) terms in ϕ. However, when it comes to a negation $\neg\phi$, the verifier gets the role of the 'falsifier' of ϕ, who has to refute any attempt to verify ϕ by somebody else. Under this *GTS* outlook upon negation it may be clear why indefinites under a negation are not any longer associated with referential intentions. When a speaker asserts $\neg\phi$, the indefinites in ϕ do not belong to her (pragmatic) jurisdiction so to speak, but to that of any potential antagonist who could come by so as to assert that ϕ. By stating $\neg\phi$ the speaker thus rejects any use of ϕ with whatever referential intentions.[31]

The conception of negation as a role switcher has a further pay off when we consider the assertion of conditional sentences $\phi \rightarrow \psi$, which are defined in terms of negation (and conjunction). For instance, the evidence which a speaker may bring to bear upon her assertion of a conditional sentence can be seen to consist in her evidence for the consequent of the conditional, were she to accept anybody else's evidence for the antecedent.[32] Not only does this provide motivation for the often attested existential closure over the indefinites in the antecedent of a conditional, but it also suggests the speaker's evidence for the consequent clause to be functionally dependent on the possible witnesses for these indefinites. As we will see below, the functional type of support which the speaker can be required to have for indefinites in the consequent clause can be cashed out by subsequent pronouns, if these are also read functionally.

Like we saw, the typical impact of negations (and implications) can be spelled

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30. In *PLA*, as in most other systems of dynamic interpretation, negation really acts as a denial of truth, for $\neg\phi$ is satisfied by $\vec{e}$ if and only ϕ is not true relative to $\vec{e}$. The reason is that our truth-definition also invokes an existential closure of the open places related to indefinites, and this type of closure we claim to be intuitively motivated. For, like we said, the referential intentions associated with indefinites are of a pragmatic nature, and these ought not to affect basic semantic notions like that of truth (and falsity, for that matter). So, although we hold that the referential intentions associated with indefinites affect the interpretation of subsequent pronouns, we do not want to bring them to bear upon the evaluation of the assertions in which they are used, be it as true or false.

31. Interestingly, the idea of negation as a role-switcher is also fruitful when we are to specify both what a speaker's support for an assertion may consist in and what may be the hearer's update of information when he accepts the speaker's utterance. It then turns out that *speaker's support for* $\neg\phi$ is most adequately defined in terms of the absurdity of *her update with* ϕ. Cf. (Dekker 2002) for details and further discussion.

32. Recall that $\phi \rightarrow \psi$ is defined as $\neg(\phi \wedge \neg\psi)$. If we use this definition of $\rightarrow$ in the support and update calculus of (Dekker 2002, cf. the previous footnote), *a speaker's support for* $\phi \rightarrow \psi$ turns out to consist in *her support for* ψ after *her update with* ϕ.

out, in an intuitively appealing way, in terms of a *GTS* game between a speaker (or verifier) and a (virtual, or abstract) respondent (or falsifier). However, we think, the pragmatic division of labour at issue is more general than the one accounted for in the framework of game theoretical semantics.

Coherent discourse and dialogues generally consist of assertions which have an (explicit or implicit) 'background' or 'topic' part, and an (explicit) 'focus'.[33] Typically—that is, if context or intonation have no interfering effects—one could say that e.g., the contents of negated sentences, the antecedents of implications, and the restrictions on quantifiers constitute a background or topic, which the speaker is not automatically supposed to support, but which she is supposed to react upon. It is the focus part of her utterance which she can be required to have support for, possibly in functional dependence on such a background.

Given this it is no mystery that, by default, indefinites in the background part of an assertion do not introduce possible referents for pronouns used in subsequent utterances. Since the speaker need not be required to support that part of her utterance, these indefinites fall beyond her 'pragmatic jurisdiction', so to speak, and they are not assumed to be used with referential intentions. Indefinites in focus, however, do require speaker's support, and generally are associated with referential intentions. However, since the focus may be functional on a background, the referential intentions associated with indefinites in focus may be functional, too.

Interestingly, this view upon the matter suggests or even predicts that anaphoric pronouns may refer back to such functional witnesses. And this 'prediction' is indeed born out. Consider the following examples, known from the literature:

(19) If a book is printed with Kluwer it has an index. It can always be found at the end. (after Heim)

(20) Harvey courts a girl at every convention. She usually comes to the banquet with him. (after Karttunen)

Support for an utterance of the first sentence of (19) may consist of a witness function f, assigning indices to books printed with Kluwer. If the speaker has such a function in mind, then she may refer back to it with a pronoun when she subsequently utters the second sentence. The second utterance then is assumed to be about books printed with Kluwer, too, and expresses that, always, if b is a book printed with Kluwer, then $f(b)$ can be found at the end of b.[34] Something essentially similar holds of example (20). Assuming that an utterance of the first sentence of this example is supported by a function g, which associates girls which Harvey courts with the conventions he visits, an utterance of the

33. Cf., e.g., (Jackendoff 1972, Ch. 6, Karttunen and Peters 1979, von Stechow 1991, Rooth 1992) for a number of formally quite different implementations of this distinction, which we, however, think are really close in spirit to the one we have in mind. Notice that, when we use the term 'focus', we do not mean 'contrastive focus' here.

34. The term "the end" thus is supposed to be functional, too.

second sentence refers back to it and states that for most c, if c is a convention which Harvey visits, then $g(c)$ accompanies Harvey to the banquet of c. Let us note that these readings can be derived compositionally by combining the techniques from (Jacobson 1999) with the account of anaphoric relationships presented in this paper.[35] So, summing up the findings of this section, we may observe that the blocking effects coming from, among others, negations, are indeed intuitively motivated, and that besides, the empirically attested leaks from such blocking contacts are indeed predicted.[36]

Conclusion

In this paper we have shown that indeed, as argued in (Stalnaker 1998), cross-sentential anaphoric relationships can be accounted for on the basis of a classical, static, notion of meaning. A systematic elaboration of the observations made in that paper, however, forces us to take into account the dynamics of assertion, which, basically, consists in the fact that assertions are made one by one, in a linear order.

We have shown that the dynamics of interpretation can be located in the dynamics of conjunction. In the minimal system of *PLA* the dynamics of interpretation is modeled by a notion of conjunction which explicitly accounts for the fact that one conjunct literally precedes the other. Other systems of dynamic interpretation (like that of Heim 1982; Groenendijk and Stokhof 1991, among many others) can be argued to account for the same phenomena in a different manner, but with the same intuitive, and if you want philosophical, motivation.

Interestingly, it is not so much the dynamics of interpretation that is puzzling, but, rather, the lack of it, in certain contexts. We have argued, like others before us, that definite and indefinite terms generally are, or ought to be, used with referential intentions. Indefinite terms, however, are typically not used this way when they figure in the scope of a negation, in the antecedent of a conditional sentence, or in the restriction of a quantifier (adnominal or adverbial). So far, it has remained unclear in the literature why this is so.

In the last section of this paper we have argued that the 'blocking effects' of these constructions—which are certainly not unavoidable—relate to

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35. It may be needless to say that a functional reading of a pronoun is technically more complicated and that it imposes very specific demands on possible contexts of use. It is, thus, to be expected that they are much more marginal than non-functional ones. The same goes, mutatis mutandis, for the functional readings of (in)definites and *Wh*-items discussed by Jacobson, among many others (cf., the references in (Jacobson 1999).

36. Notice that we have neglected, here, how the restriction of the quantifiers *always* and *usually* is accommodated in the examples (19) and (20). Arguably, this involves another instance of anaphoric resolution, for which there are several analyses on the market. Notice, too, that in whatever we way account for this kind of accommodation, it will also enable us to refer back to indefinites in the antecedent of, for instance, the first sentences of (19), by employing the identity function.

the typical role of these constructions in discourse and dialogue. Negations can be used to reject a proposition which has been raised in a discourse, explicitly, because somebody else asserted it, or implicitly, because it is deemed to be likely, or relevant; a conditional sentence can be used to expand upon the consequences of a possibility, stated by the antecedent of the conditional, which is deemed relevant; and quantifiers are typically used to assert something of their (presupposed) domain of quantification. In either case the speaker can be held responsible for what she asserts about what is given, but not for what constitutes the background of her assertion. For this reason the speaker can not (in general) be required to be able to supply witnesses for the indefinites used in characterizing the background.

Let us spend a final word on utterances other than assertions, viz., questions and orders. It seems that, typically, indefinites in interrogatives and imperatives are used without referential intentions too. This blocking effect can be given the same pragmatic explanation as the blocking effect of backgrounds. For if someone asks:

(21) Is there is a hammer in the toolkit?

she is of course not required to have evidence that there is one; rather, she can be required not to know there to be one. Similarly, if she orders you:

(22) Put a red block on a blue one.

she is not supposed to have evidence supporting the fact that there is a red block on a blue one. Rather, for such an order to make sense at least one red block should not be on a blue one.

With questions and orders, there is, however, further reason for not using indefinites with referential intentions. For if one asks:

(23) Is there a man in the house?

with a very particular man in mind, the speaker does not enable the hearer to answer appropriately. Given that, in such a counterintuitive, or non-cooperative, case, the speaker does not specify whom she is asking a question about, the hearer cannot figure out which question the speaker really wants an answer to, and the question would be odd, at least. Similarly, if you order me to bring you a specific book from the table by uttering:

(24) Bring me a book from the table.

and if there are quite a few of them, I cannot carry out the desired request if I fail to know which book you want. Also in these cases we see that pragmatic principles, this time those concerning questions and requests, conspire so as to undo the effects of principles governing the use of indefinite noun phrases.

To conclude, let us recapitulate what we have done in this paper. Systems of discourse representation and dynamic semantics have been developed to account for, among other things, intersentential anaphoric connections between indefinite noun phrases and anaphoric pronouns. Apparently, the success of

these systems derives from the fact that they adopt an essentially richer notion of meaning, a representational or a dynamic one, respectively. Following (Stalnaker 1998), we have argued that the phenomena do not, however, require such an extended notion of meaning. Pronouns can be taken to be ordinary referring devices, which can refer anaphorically to individuals which have been made 'intentionally present' by previously used indefinite noun phrases.

However, in contrast with Stalnaker, we have next argued that a systematic account of the interpretation of discourse after all does provide motivation for a dynamic notion of interpretation. If indefinites indeed can be used so as to provide, in an indefinite way, possible referents for subsequent pronouns, and if our system of interpretation aims to account for that, then the possible referents must be taken up in some way, and be dealt with in an orderly way.

Systems of discourse representation and dynamic semantics then can be seen to do precisely this. By means of the dynamic system of interpretation of *PLA*, we have shown that a systematic and dynamic account of the data indeed can be seen to derive from a classical semantics, extended so as to take (the effects of) certain pragmatic principles into account. Classical semantic properties of sentences are dealt with in *PLA* in tandem with an account of systematic pragmatic facts related to their use. As we have seen, all non-standard features of the *PLA* satisfaction relation have been traced back to pragmatic principles related to the use of its formulas, or, rather, of the natural language sentences whose contents these formulas can be taken to model. By doing so, we have also shown that the dynamics of interpretation can be attributed, entirely, to the dynamics of conjoining assertions, one after the other.

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