On Context and Identity*

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Abstract
A range of phenomena in (discourse) semantics has prompted a dynamic notion of meaning, spelled out as an update function on a domain of information states. In this paper we study the relation between information states and the world about which they are supposed to contain information. We will propose a formal system in which a dynamic/epistemic notion of meaning is reconciled with insights from Kripke and Kaplan on the epistemics of demonstrative reference, and we will show how it successfully applies to puzzles discussed by Frege, Kripke and Quine.

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Introduction

The focus of substantial parts of nowadays semantics has shifted from the information content of sentences tout court, towards the sentences' dependence and effect on the context of interpretation. Over the last couples of years, a whole array of theorists, inspired by the work of Stalnaker, Kamp and Heim, have in one way or another adopted the perspective upon a sentence meaning as that of a context change potential. This perspective upon meaning has been fleshed out within a semantic theory in a number of different ways. One of these consists in modeling the ways in which the interpretation of a sentence induces a transition of information. Starting of from a notion of information, and a way of modeling that kind of information within a formal space of information states, the interpretation of a sentence is defined as an function on that domain of states.

The sketched perspective upon meaning also characterizes the semantic approach adopted in this paper. The present approach is more in particular

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characterized by what has also been called, ironically, the 'minimalist' program in semantics. Roughly, and basically, the idea behind this program is to select a (small) number of aspects of natural language interpretation which are assumed to be of special interest, and then to sort out the minimal notion of information structure required to account for those. Focussing on a restricted domain of phenomena, it is more likely that the issues involved can be studied in full generality, and thus, one of the ideas is, one should be able to lay bare the underlying logic. Accompanying idea is, furthermore, that, precisely since the issues are studied in full generality, the resulting analyses of different issues must in principle be combinable, and conceived of as preparatory phases of much more elaborate and sophisticated systems of natural language interpretation. It may be noticed that this formal outlook on meaning, or interpretation, contrasts with a cognitive psychological or an AI one. Our primary aim is that of constructing formal models mimicking certain semantic data, and questions about their psychological plausibility or computational tractability are just not taken into account, at least not in the first place.

In this paper the focus is upon identity, or, rather, the interpretation and information content of identity statements. Of course, it goes without saying that this issue is an outstanding philosophical problem, and the first thing to be made clear from the outset is that, in accordance with the sketched minimalist program, we will only try to approach this issue from a purely semantic point of view. For one thing, we will only be concerned with ((models of) information about) discrete objects, not about non-discrete parts of the world, or about more abstract objects, such as, for instance, events, emotions, properties, or what have you. For another, these objects will only be addressed from a small formal language, viz., a version of first order predicate logic which is enriched with additional categories of anaphoric pronouns and demonstratives. And yet, we will not even offer a substantial theory of anaphora, anaphora resolution and natural language indexicality, but confine ourselves to an epistemic account of the semantics of demonstrative and anaphoric reference.

Of course, also within the philosophy of language much attention has been paid to the semantics of identity statements, and the work of Frege, Kripke, among others, may bear witness of that. We hope that the reader will be able to retrieve enough of the issues that have been discussed in that tradition, but the problems and analyses that have occurred need not recur in their original vein below. Although the importance of the epistemic states of language users has always been acknowledged, the issues can now be discussed against the background of an epistemic theory of interpretation. Our aim is to find a notion of information—or, rather, a way of dealing with an independently motivated notion of information—which allows us to live up to the following assumptions. First, that it needn't be immediately obvious from a given an object which object that is. Put differently, that there is nothing contradictory about being mistaken about the identity of a given object. Second, that, nevertheless, there is a perfectly legitimate notion of information about objects, which is a notion of information about the real individuals which are 'out there' in the world.

A warning is in order here, too. This paper reports on work in progress. Its architecture still reflects a flow of thought, and it hasn't yet condensed into a firm statement of opinion and study of the logic that this gives rise to. It is only in the concluding section that the findings are collected and mould into a more simple picture. Errors must be there. They are mine.

1 Modeling Information

The kind of information we will be dealing with in this paper is information about the world and its residents. What we would like to model is the possible states of affairs that may obtain in our world, what properties individuals have and in what relations they stand. As a first upshot information about this kind of subject matter will be cast in terms of the possible extensions of the individual and relational constants of a first order language. Their possible extensions are defined in relation to so-called possible worlds, and these worlds may be conceived of as constituting the possible alternatives ways the world might be. Thus, as is done quite generally indeed, a state of partial information about how the world is can be modeled by means of a set of possible worlds. A set of possible worlds s models an information state i if, intuitively speaking, s is the set of worlds which are all compatible with the information in i. Each world in s thus can be taken to characterize a possible extension of i into an (idealized) state of total information. In order to make it more concrete, suppose the information you have about the world coincides with the (supposedly correct) information you have about your immediate surroundings. Then every possible total extension of these surroundings can be conceived of as a possible world compatible with your information, and among this set of possible worlds you can find the actual world: the actual total extension of these surroundings.

So, to begin with, information is modeled against the background of a set of possible worlds W, and an interpretation function F which interprets the constants of a formal language relative to possible worlds. Thus, we can say that an information state $s \subseteq W$ contains the information that it rains iff there is a 0-place relational constant p associated with the proposition that it rains, and such that for any world $w \in s$: the interpretation $F_w(p)$ of p in w is 1, i.e., true. Also, such an information can be taken to model that, say, Ella accompanied Otto to Prague, iff, equating 'accompany', 'Ella', 'Otto', and 'Prague' with A, e, o, and p, respectively, for any world $w \in s$, the referents of e, o, and p in w stand in the relation assigned to A in w (i.e., iff $\langle F_w(e), F_w(o), F_w(p)\rangle \in F_w(A)$). Here it may already be noticed that it is not at all excluded that individual constants may refer to different individuals in different possible worlds. This may seem at odds with the doctrine of rigid designation very convincingly put in the work of Kripke. However, notice that we are not (in the first place) dealing with reference, but with partial information about the extensions of constants, and that it is in full accordance with the work of Kripke (and others) that the metaphysically rigid nature of the reference of proper names apparently exceeds the epistemic perspective of linguistic agents. Here we hit upon a subtle difference which we cannot afford ourselves to discuss fully in the present context. The difference is that between epistemic alternatives for the real world on the one hand, which can be used to characterize our more or less platonic information states; and, on the other hand, the 'metaphysical' or 'ontological' alternatives of a world which is assumed to be real. The last ones of these can be taken to be used in counterfactual reasoning, and with respect to a–believed to be actual–world w, such counterfactual or ontological alternatives w' will be taken to observe the principle of rigid designation (i.e., that $F_{w'}(c) = F_w(c)$ for any constant c). Epistemic alternatives on the other hand do not obey this principle, and, apart from that idea being mould in a possible worlds framework, it is at least as old as the work of Frege.

The sketched kind of information does not exhaust the type of information we want to model in this paper. We do have a lot of information about 'individuals' which we are unable to identify. We may have gathered whole bunches of information about individuals which, later, we cannot reidentify anymore; also, we gather a lot of information about individuals from hearsay, in which individuals are introduced to us by a proper name, or even an indefinite description ("a man I met yesterday"). Characteristic property of such 'individuals' is that they are very partial objects indeed, and that they are given to us *only* by the properties attributed to them. If we assume that all we know about such an 'individual' is that it is someone with the property Φ, where in Φ all the information is gathered we have about that individual, then we might say of such an individual, adopting the terminology of Kit Fine Fine 1984, that it is an 'arbitrary Φ'. And, like Fine, we might associate such an 'arbitrary Φ' with all the possible instantiations of Φ. If such an arbitrary object is known to us as "a man who climbed the Eiffel Tower", then it can be modeled as set of world-individual pairs $\langle w, d\rangle$, such that the individual d is a man in w who climbed the Eiffel Tower in w. There is one more interesting thing about such arbitrary objects, which are called 'subjects' in the sequel, and that is that they are highly dependent upon one another in general. So, we may speak of an arbitrary farmer and an arbitrary donkey the farmer owns, or we may speak of a man who wanted to climb the Eiffel Tower and a man who persuaded him not to do so. In such cases a possible instantiation of one subject restricts the possible instantiations of the other, and vice versa. Thus, if we for one moment forget the relation with possible worlds, and fix one as the actual, we see that, although one arbitrary object can be modeled by means of the set of its possible instantiations, a set of individuals, that is, still a pair of arbitrary objects has to be modeled, not as a pair of sets of individuals, but as a set of pairs of indivduals, and, likewise, an n-tuple of subjects has be modeled, not as an n-tuple of sets of indivduals, but as a set of n-tuples of individuals. Now, in order to couple this notion of information about subjects with the notion of information about the world introduced above, we can say that a state of information about n-subjects consists of a set of $n+1$-tuples, the first element of which is a world w, and the other n elements of which constitute a tuple of individuals which instantiates the n-subjects in w. And we will say that a state s of information about 2 subjects is about a farmer and a donkey the farmer owns, if for any tuple $\langle w, d, d'\rangle \in s$ we find that d is a farmer in w, d' a donkey in w, and d owns d' in w.

Before we turn the above observations into more tractable definitions, there is one more thing we have to pay attention to. We will assume that possible worlds not only may differ from one another with respect to the interpretation of constants, but also with respect to the domain of individuals that may be said to exist in those worlds. In this respect we explicitly deviate from the otherwise intimately related approach taken by Groenendijk et al. 1994. In that paper the notion of information studied is restricted to the notion of information about a delineated domain of individuals. The idea is that the updates of information to be modeled are updates of information about the properties of these individuals only. The identity and the number of individuals in this domain is assumed to be fully determined in each possible state of information about this domain, and it is also assumed that every individual can be demonstratively referred to. Here, we want to adopt a more liberal perspective. We start of from the assumption that there are individuals which are, as it were, immediately given to us, but we do not assume that these are all the individuals we (can) have information about, and we let our quantifiers range over all the individuals which might turn to out to be there in the world, not just the ones we are directly acquainted with. Furthermore, we drop the assumption that we know how many individuals there are, that is, we accept epistemic possibilities in which there turn out to be less, more, or just any different number of individuals then there actually are. This means, in fact, that the extension of a constant of our language should not be made up from one domain of individuals, but, if it is the extension of a constant in a world w, from the domain of individuals belonging to w. In short, we assume models which, next to a set of worlds W and an interpretation function F, incorporate a domain function assigning a domain of individuals to each world $w \in W$. Moreover, it is required that the interpretation function F assigns only extensions to constants in a world which are (made up of) individuals existing in that world. In this paper we are not dealing with information about 'non-existent' objects, 'possible' individuals or fictional discourse.

We now can turn to a general definition of the models we use, (in which a particular language of first order predicate logic is presupposed), and the information states they give rise to:

Definition 1 (Models) A models M is a triple $M = \langle W, D, F\rangle$, with W a set of possible worlds, D a domain function, assigining each world w its domain of individuals D_w, and F an interpretation function, which assigns extensions to the individual and relational constants of our language in each world. The extension of any constant in a world w belongs to the domain D_w of w.

This definition formally captures the outlines of a model as discussed informally sofar. Reference to a model M will be suppressed as much as possible in what follows. The next definition is that of our notion of an information state. In the first place, these will be called *situated* information states for reasons which will become clear in the sequel (viz., section 4).

Definition 2 (Situated Information States)

$S^n = \mathcal{P}(\bigcup_{w \in W}\{w\} \times D^n_w)$ is the set of information states about n subjects

$S = \bigcup_{n \in \mathcal{N}} S^n$ is the set of all information states

(Taking D to be $\bigcup_{w \in W} D_w$, we might as well have defined S^n as $\mathcal{P}(W \times D^n)$, and have restricted ourselves to what then might be called 'proper' information states, viz., those information states which support the existence of their subjects. The difference is immaterial for our present purposes.) In general, for any $s \in S^n$ and $e = \langle w, \langle d_1, \ldots, d_n\rangle\rangle \in s$, we will write e as $\langle w, d_1, \ldots, d_n\rangle$, and we let $e_i = d_i$ and $w_e = w$. An information state s about n subjects can then be pictured as follows:

$$\left\{\begin{array}{c}\langle w, d_1, \ldots, d_n\rangle \\ \\ \vdots \\ \\ \langle w', d'_1, \ldots, d'_n\rangle\end{array}\right\} \qquad \begin{array}{l}\nwarrow \\ \leftarrow \ \text{Possible cases} \\ \swarrow\end{array}$$

$$\nwarrow \uparrow \nearrow$$

Possible values
of subjects

Assuming that $0 < i, j \leq n$, the above information state s models the information that the i-th subject is a man who wanted to climb the Eiffel Tower, and the j-th subject a man who dissuaded him from doing so, iff, for any $\langle w, d_1, \ldots, d_n\rangle \in s$, d_i is a man in w who wanted to climb the Eiffel Tower in w, and d_j a man in w who dissuaded d_i from doing so in w. Thus, such an information state models the presence of two indefinite subjects, as well as the information that the world is such that there is a man in there who wanted to climb the Eiffel Tower who was dissuaded from doing so by another man. If there were no two such men in a world w', then there would be no such tuple $\langle w', d'_1, \ldots, d'_n\rangle$ in s.

Having defined our notion of information, or—if you want—our way of modeling information, we must see what it means to get more information. In the system of epistemic predicate logic presented below all formulas are interpreted as functions updating information states, and this notion of updating will be taken in a very precise sense. Update of information in this paper will be associated with proper *addition* of information, not mere change. Basically, update of information can come about in two ways. In the way information is conceived of in this paper, growth of information may consist in getting more informed about the world and the subjects introduced, or in getting (informed about) more subjects (or, of course, in a mixture of both). The first aspect of information growth boils down to reducing the set of epistemic alternatives. By learning what the world is not like, or by excluding possible instantiations of a subject, one gets more information, correct or incorrect, about how the world is, and about which individuals its subjects in the end may turn out to be. The second aspect of information growth merely boils down to extending the possibilities in an information state. Putting things together, an update of a state s is a state that consists, only, of extensions of possibilities in s. Here, and in what follows, $\cdot$ indicates concatenation (if $e \in D^n$ and $e' \in D^m$, then $e \cdot e' = \langle e_1, \ldots, e_n, e'_1, \ldots, e'_m\rangle \in D^{n+m}$), $\leq$ extension ($e \leq e'$, iff $\exists e''$: $e' = e \cdot e''$), and N_s or N_e the number of subjects of s or e (for $s \in S^n$, $e \in D^n$, $N_s = N_e = n$).

Definition 3 (Information extension)
State s' is an update of state s, $s \leq s'$, iff $N_s \leq N_{s'}$, and $\forall e' \in s' \ \exists e \in s$: $e \leq e'$

The update relation can be pictured in the following way:

$$\left\{\begin{array}{c} \langle w, d_1, \ldots, d_n \rangle \\ \vdots \\ \langle w', d'_1, \ldots, d'_n \rangle \\ \vdots \\ \langle w'', d''_1, \ldots, d''_n \rangle \\ \vdots \\ \langle w''', d'''_1, \ldots, d'''_n \rangle \end{array}\right\} \leq \left\{\begin{array}{c} \langle w', d'_1, \ldots, d'_n, d'_{n+1}, \ldots, d'_{n+m} \rangle \\ \vdots \\ \langle w'', d''_1, \ldots, d''_n, d''_{n+1}, \ldots, d''_{n+m} \rangle \end{array}\right\}$$

This figure must be taken to show that if s' is an update of s ($s \leq s'$), then all possibilities in s' are extensions of possibilities in s. Some possibilities in s, however, need not have an extension in s'. In what follows, in case a possibility $e \in s$ has an extension in an update s' of s, we will say that e survives in s'; and in case a possibility in s does not survive in the update s', we will say that the update rejects e. Let us conclude this section with the following observation:

Observation 1 $\langle S, \leq \rangle$ is a partial order

Obviously, and appropriately, information growth is transitive, reflexive and antisymmetric.

2 An Epistemic Predicate Logic

In this section we will turn to the interpretation of a language of first order predicate logic which is constructed like that of ordinary predicate logic but which, apart from the categories of (individual) constants and variables, also employs a category $\mathtt{A}$ of anaphoric pronouns ($\mathtt{p}_0, \mathtt{p}_1, \ldots$), and a category $\mathtt{D}$ of demonstratives ($\mathtt{d}_1, \mathtt{d}_2, \ldots$). The interpretation of this language is defined as a function updating information states. This whole system is called epistemic predicate logic *EPL*. Pronouns are interpreted as referring back to subjects ('discourse referents') which have been introduced by indefinite noun phrases (existential quantifiers) in preceding discourse. Demonstratives are taken to refer to contextually supplied individuals. It may have to be stressed here that what is offered is not a theory of anaphora, of anaphora resolution or of demonstrative reference. Our interest lies in the semantics of identity statements, conceived from an epistemic perspective, and in the appropriate notions of information structure needed to account for that. For as far as this is related to anaphoric and demonstrative reference, our aim is that of modeling the interpretation of anaphoric relationships and the informational impact of demonstrative reference. But for this purpose the various ways in which specific anaphoric relationships and demonstrative links are established can be left out of discussion.

Without going into any detail, we will just sketch the general ideas here. For a better exposition of the system, and for more discussion, the reader is referred to Dekker 1994.

The idea of this interpretive system is that the interpretation of an (indicative) sentence by an agent who has no reason to reject the sentence, leads to an update of his information. So, we will give a recursive specification of the results of updating information states with the formulas of this language. As usual, this specification is given relative to a model and an assignment function. Possible models are the models we have introduced in the preceding section, and assignments are the usual functions assigning individuals to variables. Obviously, we need variable assignments in order to interpret subformulas of quantified formulas, and it is equally clearly possible that such variable assignments may have individuals in their range which do not belong to the domain of (all of) the worlds conceived possible in the information state in which interpretation takes place. However, since we will assume to be talking about sentences and sequences of sentences only, i.e., (sequences of) formulas without free variables, and since our quantifiers are defined to range only over individuals which are acknowledged to be existent, we need not bother about the deviant cases in which a formula is evaluated against the background of a possible world in which any of the values of the formula's terms do not exist.

Apart from our focus upon the addition of information brought about by the interpretation of a sentence, rather than upon the amount of information expressed, the interpretation function is relatively classical indeed. Relative to an epistemic possibility (a world plus a sequence of individuals) an atomic formula is considered to be satisfied iff the values of its terms relative to that possibility stand in the expressed relation relative to that possibility. If such a formula is satisfied in this way, the possibility is retained, otherwise it is rejected. Of course, there is something less standard about the interpretation of atomic formulas, because some of its terms may be pronouns or demonstratives. As has been said above, a pronoun refers back to an individual introduced by a preceding existential quantifier, which, as we will see in a little more detail below, has been coded up as a subject of an information state. In particular, its value is taken to be an element of the sequence of individuals against the background of which the pronoun is evaluated. For the sake of simplicity we assume that a pronoun $\mathtt{p}_i$ is associated with the $i+1$-th last subject of the state s with respect to which it is evaluated. (If it exists, that is; otherwise, the interpretation of the pronoun will be undefined.) This means that relative to a case $e \in s$, the value of $\mathtt{p}_i$ is $e_{N_s - i}$. In short, the pronoun with the index 0 picks out the subject introduced last, and its value is the last individual of any case (sequence) to which it applies; the pronoun with index 1 picks out the second last mentioned subject, etc., etc.

The demonstrable objects in the domain of discussion are represented by a case, a tuple of individuals. These sequences are steady contextual parameters of interpretation. Demonstratives are taken to select an object from the contextual parameter, and, in order to keep things simple, we assume that for any parameter $f = \langle d_1, \ldots, d_n \rangle$, the value $[\mathtt{d}_i]^f$ of $\mathtt{d}_i$ with respect to f is f_i, if it exists. A final assumption is that objects can only be demonstratively referred to if they are acknowledged to exist. So, we will say that s is appropriate for a case f, with $f \in D^m$, only if $\forall e \in s\ \forall i\ 0 < i \leq m$: $d_i \in D_{w_e}$. Unlike the other restrictions we discussed, this restriction may seem to be an ad hoc restriction upon what are possible parameters of interpretation. However, given a parameter of interpretation f, it can also be conceived of as a precondition for interpretation. In order to update an information state s relative to f, s must be updated, first, with the information that all elements of f exist. (And it may be noticed here, furthermore, that the very same restriction will be captured in the next section without reference to parameters of interpretation.)

To sum up, the general format of interpretation is that of a (partial) update function on information states $[\![\ ]\!]^f_{M,g}$, with ordinary fixed parameters M and g, and a fixed contextual parameter f. The application of this function to an information state s, written as $s[\![\ ]\!]^f_{M,g}$, has an updated information state as result (if it is defined, that is). Before we turn to the interpretation of our formulas, we have to define the interpretation of our terms. In an information state s these are evaluated with respect to the first three parameters, M, g and f, and each possibility $e \in s$:

Definition 4 (Interpretation of Terms)

$[c]^f_{M,g,e} = F_{w_e}(c)$ for all constants c

$[x]^f_{M,g,e} = g(x)$ for all variables x

$[\mathtt{p}_i]^f_{M,g,e} = e_{N_e - i}$ for all pronouns $\mathtt{p}_i$ such that $N_e > i$

$[\mathtt{d}_j]^f_{M,g,e} = f_j$ for all demonstratives $\mathtt{d}_j$ such that $N_f \geq j$

With respect to some model M and possibility e which includes a world w_e, the value of an individual constant is the value assigned to it by the interpretation function F_{w_e} in w_e. The value of a variable is the value assigned to it by the variable assignment with respect to which interpretation takes place. As has already been said, a pronoun refers to a subject in the state of information in which it is evaluated. With respect to each possibility e in an information state s, its value is the element in e which occupies a fixed position. A demonstrative selects a contextually supplied object.

Before we turn to the interpretation of formulas, a comment is in order on definedness and resolvedness. Since pronouns and demonstratives may fail a denotation with respect to a state s and a case f, atomic formulas may be undefined. Undefinedness percolates up in the following way. If ϕ is undefined with respect to s and f, then so are $\neg\phi$, $\exists x\phi$ and $\phi \wedge \psi$. Furthermore, if ψ is undefined with respect to $s[\![\phi]\!]$ and f, then $\phi \wedge \psi$ is undefined with respect to s and f. Notice that a pronoun in a formula ψ need not be necessarily defined, since it presupposes the presence of a certain number of subjects, while it is defined in the conjunction $\phi \wedge \psi$, that is, when ϕ involves the introduction of at least that number of subjects. We will say that a pronoun in a discourse is resolved if it refers to a subject introduced in that very same discourse. A demonstrative is resolved if it is defined with respect to the contextual parameter f. If all the pronouns and demonstratives in a discourse are resolved, then the discourse itself is called resolved. We just note that, given a fixed number of demonstrable objects, definedness and resolvedness can also be characterized syntactically. In the sequel of this paper, the possibility of undefinedness will be neglected. Let us now turn to the definition of the interpretation of our formulas.

Definition 5 (EPL Semantics)

$$\begin{aligned} s[\![Rt_1 \ldots t_n]\!]^f_{M,g} &= \{e \in s \mid \langle [t_1]^f_{M,g,e}, \ldots, [t_n]^f_{M,g,e} \rangle \in F_{w_e}(R)\} \\ s[\![t_1 = t_2]\!]^f_{M,g} &= \{e \in s \mid [t_1]^f_{M,g,e} = [t_2]^f_{M,g,e}\} \\ s[\![\exists x\phi]\!]^f_{M,g} &= \{e \cdot \langle d \rangle \mid d \in D_{w_e} \ \&\ e \in s_d[\![\phi]\!]^f_{M,g[x/d]}\} \\ s[\![\neg\phi]\!]^f_{M,g} &= \{e \in s \mid \neg\exists e' \colon e \leq e' \ \&\ e' \in s[\![\phi]\!]^f_{M,g}\} \\ s[\![\phi \wedge \psi]\!]^f_{M,g} &= s[\![\phi]\!]^f_{M,g}[\![\psi]\!]^f_{M,g} \end{aligned}$$

where $s_d = \{e \in s \mid d \in D_{w_e}\}$

As usual, we take $\forall x\phi$ and $\phi \rightarrow \psi$ to abbreviate $\neg\exists x\neg\phi$ and $\neg(\phi \wedge \neg\psi)$, respectively. In the above definition, the interpretation of atomic formulas is as it has been sketched earlier. A subject introduced by means of an existentially quantified formula $\exists x\phi$ is constructed from the possible values of x in ϕ (x's 'witnesses'). Notice that the existential quantifier (and, consequently, the universal quantifier) are interpreted in a state which is restricted to be one in which the value of the variable x which is quantified over is acknowledged to exist. Thus, this kind of quantification is really 'existential'. (And the universal quantifier, thus, quantifies over everything that exists. This use of existential updates in the evaluation of quantified formulas has been taken from an aside in a handout by Groenendijk, Stokhof and Veltman *Definite Descriptions and Update Semantics*, 1994, DYANA workshop, Edinburgh).

Just because an existential quantifier in a formula ϕ may generate a proper extension of the possibilities in an information state s in which ϕ is interpreted, its negation $\neg\phi$ in s is not properly defined in terms of the subtraction of $s[\![\phi]\!]$ from s. What has to be subtracted from s are those possibilities in s that don't have an *extension* in $s[\![\phi]\!]$. So, $s[\![\neg\phi]\!]$ consists of those possibilties in s which don't survive the update with ϕ, which are rejected by ϕ. In keeping with the functional view on interpretation, sentence sequencing, or conjunction, involves the composition of the two update functions associated with the conjuncts. In order to update a state s with $\phi \wedge \psi$, we first update s with ϕ and next update the result with ψ.

For those who haven't seen 'dynamic' or discourse representation theoretic accounts of anaphoric relationships before, we will give a very concise illustration of how anaphora are dealt with in our system, before we turn to our main issue, that of identity statements. First consider the following prototypical example of intersentential anaphora:

(1) A farmer owns a donkey. He beats it.
$\exists x(Fx \wedge \exists y(Dy \wedge Oxy)) \wedge B\mathtt{p}_0\mathtt{p}_1$

When interpreted in a state of information s, the first sentence of this example yields the following set of possibilities, state s':

(1a) $\{e \cdot \langle d \cdot d' \rangle \mid e \in s \ \&\ d'$ is a farmer in w_e
$\&\ d$ is a donkey in w_e $\&\ d'$ owns d in $w_e\}$

Because the witnessing farmer and donkey are retained as subjects in s', they can be referred back to with pronouns. The second sentence *He beats it*, with the pronouns resolved as in $B\mathrm{p}_0\mathrm{p}_1$, reduces s' to:

(1b) $\{e \cdot \langle d \cdot d' \rangle \mid e \in s \;\&\; d'$ is a farmer in $w_e \;\&\; d$ is a donkey in w_e
$\&\; d'$ owns d in $w_e \;\&\; d'$ beats d in $w_e\}$

All in all, this sentence by sentence interpretation of the above example thus yields the information that there is a farmer who owns and beats a donkey. The following examples show how anaphoric relations in our system of *EPL* can be reformulated into binding relations with the preservance of content. (The specific reductions are licensed by a general normalization procedure presented in Dekker 1994.) The following three examples all have the same information content:

(2) A man courts a widow. He impresses her.
$\exists x(Mx \wedge \exists y(Wy \wedge Cxy)) \wedge I\mathrm{p}_0\mathrm{p}_1$

(3) A man courts a widow and impresses her.
$\exists u(Mu \wedge \exists y(Wy \wedge Cuy) \wedge Iu\mathrm{p}_0)$

(4) A man courts and impresses a widow.
$\exists u(Mu \wedge \exists v(Wv \wedge Cuv \wedge Iuv))$

Notice how the pronouns under the respective paraphrases turn into bound variables. For a conditional sentence, the above normalization amounts to the following:

(5) If a farmer owns a donkey, he beats it.
$(\exists x(Fx \wedge \exists y(Dy \wedge Oxy)) \rightarrow B\mathrm{p}_0\mathrm{p}_1)$

(6) Every farmer who owns a donkey beats it.
$\forall u((Fu \wedge \exists y(Dy \wedge Ouy)) \rightarrow Bu\mathrm{p}_0)$

(7) Every farmer beats every donkey he owns.
$\forall u(Fu \rightarrow \forall v((Dv \wedge Ouv) \rightarrow Buv))$

Here one may observe that the last pronoun is in fact a bound variable.

Before we carry on, it is worthwhile to state two general facts about our interpretation function. In the first place this function is distributive:

Observation 2 $s[\![\phi]\!] = \bigcup_{e \in s}\{e\}[\![\phi]\!]$

The formulas of our system do not express global properties of information states, they are only sensitive to the individual cases in an information state. In the second place, interpretation always produces information update:

Observation 3 $\forall s$: $s \leq s[\![\phi]\!]$ (if defined)

The fact that we have a proper update semantics is convenient from a technical point of view. It enables a definition of the notion of a formula being supported by an information state simply in terms of the absence of proper update. More specifically, a formula is said to be supported if it does not convey additional information:

Definition 6 (Support and Acceptability)

s supports ϕ wrt. M, g and f iff $\forall e \in s$: $\exists e'$: $e \leq e' \;\&\; e' \in s[\![\phi]\!]^f_{M,g}$

s accepts ϕ wrt. M, g and f iff $s[\![\phi]\!]^f_{M,g} \neq \emptyset$

ϕ is acceptable wrt. M, g and f iff $\exists s$: s accept ϕ wrt. M, g and f

A formula ϕ is supported by s iff all cases in s survive the update with ϕ. That is, by interpreting ϕ in s, no possibility in s gets rejected. So, ϕ is supported by s if s already contains the information conveyed by ϕ about the world, the objects in f, and about s's subjects. State s *accepts* ϕ iff the update with ϕ does not give a collapse into the absurd state of information. So, a state is said to accept ϕ iff the information expressed by ϕ is not in conflict with the information in s. In that case one may also say that ϕ is consistent with s. We are now also in a position to state the following general equivalence. Let $\models_{PL} \phi$ mean that ϕ is true in ordinary predicate logic (*PL*) with respect to every model M and assignment g, and $\models_{EPL}$ that ϕ is supported by every state s in epistemic predicate logic (*EPL*) with respect to every model M, assignment g, and context f. Then:

Observation 4 $\models_{PL} \phi$ iff $\models_{EPL} \phi$ for any *PL* formula ϕ

The difference only comes in when we take into account formulas containing pronouns and demonstratives.

People at home in current versions of update semantics may observe that we have deliberately refrained from internalizing the notion of acceptability, or consistency, by adding an epistemic possibility operator $\diamond$, to the effect that $\diamond\phi$ expresses that ϕ is consistent with the current state of interpretation. There are two reasons for not incorporating it, basically. The operator is of no use to our present purposes, and it is problematic. The kind of consistency involved appears to be a speaker's notion, intuitively, viz., that of a speaker who observes of her own state that it is consistent with ϕ, whereas it is formally presented as a hearer's notion, viz., that of an interpreter who is told that his information state is consistent with ϕ. (In Dekker 1993, Ch.5 it is argued that we can make more intuitive sense of this operator within the more general setting of a theory of information *exchange*, cf., also, Groenendijk et al. 1995). Furthermore, there are some problems of a logical nature, which are discussed in, for instance, Fernando 1995 (which also contains suggestions for solutions).

Now we have developed our formal apparatus sufficiently, we are finally sofar as to turn to identity statements. First notice that our information states can be seen to deal with partial information in general:

Observation 5 If ϕ and $\neg\phi$ are acceptable then $\exists s$: s accepts ϕ and s accepts $\neg\phi$

Another way to put this is by saying that if ϕ is contingent then there is a state which allows to be updated with ϕ as well as with the negation of ϕ. Of course, and this may need to be stressed, no state can be consistently updated with *both* ϕ and $\neg\phi$:

Observation 6 If s supports ϕ then s does not accept $\neg\phi$

So, upon hearing that somebody is ringing the bell, your information need not at forehand reject anyone of the updates with *He rings and runs* and *He doesn't ring and run* (observation 5). But this state, of course, does exclude that he or she is not ringing the bell (obsrvation 6). Similar observations can be made with respect to identity statements involving pronouns and individual constants:

Observation 7 If t_i or t_j is in $C \cup \mathtt{A}$ then $\exists s$: s accepts $t_i = t_j$ and s accepts $t_i \neq t_j$

Prototypical example of this is, of course, the Fregean, epistemically contingent (or a posteriori), identity of Hesperus and Phosphorus. In the old days, people might have exclaimed things like:

(8) Maybe Hesperus is Phosphorus. Maybe not.

thus expressing that their information states were inclined to accept any one of $(h = p)$ and $(h \neq p)$, although, of course, not both. This corresponds to the acceptability of each of the two formulas in one state of information in our system. Not both can be accepted, of course, since, as soon as one has the information that Hesperus is Phosporus, then one cannot accept that Hesperus is not. (Or the other way around: if one had found out that Hesperus had turned out not to be identical with Phosphorus, then it would have been equally unacceptable to concede that Hesperus was Phosphorus after all.)

Also if only one of two terms in an identity statement is, say, an individual constant, and the other a demonstrative, there is nothing problematic about being able, in principle, to accept any one of the identity statement and its negation. So, both of the following two formulas can be acceptable in one state of information:

(9) `This` is Hesperus
(10) `This` is *not* Hesperus

You just may have no information about who or what Hesperus actually is. One may know a lot about Hesperus, among other things, that it is the same planet as Phosphorus, and one may even be able to identify the right heavenly body in the evening sky as Hesperus. But, in the morning sky somebody may point at a heavenly body, and—if one fails the information to say which one of all *these* heavenly bodies actually is Phosphorus—one's state may still accept any one, but not both, of examples 9 and 10. Again, the possibility that a demonstrated individual is the referent, so to speak, of an individual constant, and the simultaneous possibility that it is not, corresponds to what we find in the system of *EPL*. But, in fact, it must be said that with this example we already have run ahead of ourselves. The details of the case as we have sketched it are not all accounted for with the system at hand. We will return to this issue in the next section. We have to see first what happens with identity statements involving no pronouns or individual constants. These—for the remainder of this section that is—turn out to be quite rigid indeed:

Observation 8 If $t_i, t_j \in V \cup \mathtt{D}$ then $\neg\exists s$: s accepts $(t_i = t_j)$ and s accepts $(t_i \neq t_j)$

In fact, in such a case any state s supports either $(t_i = t_j)$ or $(t_i \neq t_j)$ (or both, if s is absurd). Here we have hit upon Kripke's case, one might say. The above observation tells us that our system accounts for the fact that, on the one hand, you cannot be referring to one and the same object and sensibly conceive of the possibility that it is not identical to itself; and, on the other hand, that you cannot refer to two *distinct* individuals and sensibly consider the possibility that they are one and the same. At least, that is what the observation is supposed to capture.

Let us, to conclude this section, turn to a real life example involving partial information about both subjects and objects. Suppose that you have never met Dr. Killroy, but that you have heard quite a lot about him, among other things, that he or she is present at a party you are watching and discussing with a friend of yours. Also, let the domain of quantification be contextually restricted to all the people visiting this party. Then, there is nothing inconsistent or absurd about your state of information s being such that for any individual d at that party, your state s accepts each one of $x =$ *Dr. Killroy* and $x \neq$ *Dr. Killroy* under an assignment of d to x. (If we had allowed ourselves an epistemic *might* operator, you might express this state of informational generosity by saying: *Although I happen to know he is in there, everybody might be Dr. Killroy, and everybody might not be Dr. Killroy.*) In other words, referring to any one partygoer d_i your state would accept $\texttt{This}_i$ *is Dr. Killroy* and $\texttt{This}_i$ *is not Dr. Killroy*. Nevertheless, your state would not at all accept *Dr. Killroy is not Dr. Killroy* (the reason being that no one state accepts that). Clearly, all of this is modeled (to be possible) as it should be (possible).

3 Mistaking Objects

Sofar it has been assumed, as it has been in Groenendijk et al. 1994, that we cannot be mistaken about the identity of individuals we are confronted with. (Unlike Groenendijk et al. 1994, however, we have not restricted ourselves to the cases in which these objects are the only ones that exist and the only ones we talk about and quantify over.) But, as it stands, this assumption doesn't stand closer scrutiny. Take the two cups of coffee on our table, the leftmost and the rightmost cup. We can tell them apart. If they are still there tomorrow we can still tell them apart. But if we had left office to go to bed in the meantime, we might not be sure which of the cups *now* was, say the leftmost cup *yesterday*. In this section we want to pay attention to an apparent trade-off between objects and subjects and model it using a notion of a 'global' information state.

Consider the following example. Suppose you are Mr. Phelbs, and you are sitting in the underground on your way to work. Opposite to you there is a man, who is reading his newspaper. In fact, this man is always sitting there opposite to you in the underground every morning you are going to work. Now you, i.e., Mr. Phelbs, are thinking by yourself:

> This man in front me, there is no doubt he is identical to this man in front of me. How could he possibly be not identical to himself? On the other hand, this other man sitting next to him is, apparently, different from the man in front of me. How on earth could *he*, the one next to him, be identical to *him*? There simply is no way of being mistaken about that.

So, it appears, your (Mr. Phelbs's) information supports statements asserting the identity of *he*, the man who is right now sitting in front of you, and *him*, the very same man sitting in front of you, and the non-identity of the guy right now sitting next to the man in front of you, and the guy sitting in front of you himself. So far, so good. But now let us take a look one day later, when Mr. Phelbs is again on his way to work, and sitting opposite to the man he was sitting in front of the day before. Again, there is no doubt that Mr. Phelbs knows that the man *now* sitting in front of him is identical to the man *now* sitting in front of him, and distinct from the man who is *now* sitting next to the man in front of him. But still something strange has happened. Mr. Phelbs may wonder whether the man who is right now sitting in front of him—who is the man who was sitting in front of him yesterday—is or is not identical to the man who was sitting in front of him yesterday. For, why should it be *excluded* that Mr. Phelbs is faced with, say, the twin brother of the man which faced him yesterday? But this is peculiar, really. Mr. Phelbs is certain that the man who is actually sitting in front of him is identical to the man who is sitting in front of him now, while, at the same time, he wonders whether the man who was sitting in front of him yesterday, which *is* the man who is actually sitting in front of him, is identical to the man sitting in front of him now. How can Mr. Phelbs at one and the same time doubt what appears to be so evident to him? How can that be?

Maybe we'd better ask: What happened? Is this man opposite to him maybe not *really* the same man any longer as he were yesterday? Because he has properties today other than he had yesterday, or because now he is a different time-slice or something? Or did Mr. Phelbs in the meantime *lose* information, information which he had yesterday, which enabled him to identify today's man, which is yesterday's man, with the man he had in front of him yesterday? We think both answers are very unintuitive. There is no reason whatsoever to suppose that Mr. Phelbs 'forgot' something, or to give up our starting assumption that we are dealing with discrete objects with a more or less permanent identity. And we do not need to conclude thus. All we have to conclude is that Mr. Phelbs lost, not information, but a capability, to wit, the capability to definitely identify the man who was sitting in front of him yesterday. Mr. Phelbs can identify, so to speak, the man sitting in front of him today, but he cannot for certain identify him with whom he might think was sitting in front of him yesterday. This is so because he isn't any longer able to identify the man who was sitting opposite to him yesterday. What really counts in this example is that that man has not been sitting in front of him in the meantime. And it is not the fact that the man has changed position, say, but the fact that the two have been separated in the meantime. If Mr. Phelbs had been fit enough, and if he had followed that man from yesterday morning on to his work, home again, in bed, behind his breakfast, and finally, now, again in the underground—without ever losing sight of him—then you might say Mr. Phelbs knows that the man in front of him today is the man who was sitting in front of him yesterday. (At least he seems fully justified in thinking so. It would be pretty odd, indeed, if the man he never lost sight of had turned into his own twin brother, or just in anybody else.)

Maybe we should put it as follows. When Mr. Phelbs and his man were tied together in the underground so to speak, they knew they were identical to themselves, and different from each other individual present. However, as soon as both had gone each to his own office, in principle any other individual confronted with might be and might be not identical to the man that had been sitting in front of them. But then, it appears, it was not just a property of Mr. Phelbs's information state, that he was able, yesterday, to identify the man who was sitting in front of him yesterday with the man who was sitting in front of him yesterday, but it was a property of his information together with the situation he was in, the situation of sitting opposite to the man in front of him. And then it would be wrong to attribute it to his information state that he was able to make the proper identifications in the first place. Detached from the situation where they both were present, Mr. Phelbs's men is no more then a subject to him.

Of course, it might have been expected that something tricky were to occur with our first attempt at extending our epistemic semantics with demonstratives. As, among others, Kaplan has pointed out, demonstratives are prime examples of directly referential terms, and, as he and Kripke, among many others, have argued, the full identity of individuals referred to may escape our epistemic reach. The point is that there appears to be a gap between the epistemological and the ontological aspects of demonstrative reference. And in fact, the situation as it has been described sofar is another variation again upon the theme of Hesperus and Phosphorus, endlessly meditated upon by Frege, Kripke, Kaplan, Lewis, and Perry, among too many others. We think one may be quite right in saying that some fresh agent Herman knows that the object in the evening sky, which in fact is Hesperus, is Hesperus, when he says, pointing to that object, that it is Hesperus. In that situation we think it just holds true that Herman knows of that object that it is Hesperus. And completely the same story may hold of our morning session, where Herman pointing at Hesperus says: "Look, I know that thing over there is Phosphorus." In that situation we think it holds equally true that Herman knows of that object that it is Phosphorus. But then, are we forced to conclude that Herman knows that Hesperus is Phosphorus? Old wisdom has it that he need not know that the thing pointed at in the evening is in fact the same thing as the one pointed at in the morning. Whatever the object is that Herman is confronted with in the evening, when he is looking at that object in the evening he knows that it is Hesperus. But, in the non-ontological, but epistemological sense of *might*, it *might* in principle have been a completely different object without Herman being able to notice any difference. As Kripke puts it: "And so it's true that given the evidence that someone has antecedent to his empirical investigation, he can be placed in a sense in exactly the same situation, that is a qualitatively identical epistemic situation, and call two heavenly bodies 'Hesperus' and 'Phosphorus', without their being identical" Kripke 1972, pp. 103–4.

What we have failed to account for sofar, then, is the fact that the plain evidence of identity statements concerning demonstrated objects does not derive from our information about these objects, but from our information as it is somehow tied to the situations in which we find ourselves with them. The fact that we cannot mistake two apparently different *objects* for one another, is not because we have so much information that we can, always, tell these objects themselves apart, but because they are evidently present as different objects in one situation. And, the fact that you could not fail to see that it was this man in front of you who was sitting in front of you in the underground, derives from the fact that he *was* sitting in front of you, but that fact does not imply that any time you run into him it is evident to you that the man you run into was the man who was sitting in front of you in the underground. If we want to account for the (structures of) information involved in these and similar cases, then we have to detach the credited situational aspects of situated information states from these states themselves. More concretely, we have to detach the individuals we have information about from the information we have about them.

In order to represent our information proper, with the situational aspects removed from it, we have to abstract over the individuals which can be, or could have been, the instantiations of the objects one seems to be confronted with. Such a 'global' information state then is a function, from tuples of objects to what we have called situated information states sofar. In actual practice, in a situation of information exchange that is, such a function is applied to the tuple of individuals one is in fact acquainted with, but the identity of the individuals one is acquainted with is not fully determined by the information state itself (because it might have been applied to a *different* tuples of individuals, one just can't tell). Actually, this turns the 'objects' of information states into a kind of subjects. They are mere (tuples of) possible instantiations, like our subjects. Still, they do retain a special status, which makes them different from subjects. They are objects we are directly acquainted with, although we are no longer assumed to know their full identity. Our notion of an information state is, thus, generalized in the following way. (Alternative formulations are possible, of course, but this one sufficiently serves our purposes). For $m, n \in \mathcal{N}$, we give the following definition of $\Sigma^{m,n}$, the set of (global) information states about m objects and n subjects:

Definition 7 (Global Information States)
$$\Sigma^{m,n} = \{\sigma \in (S^n)^{D^m} \mid \forall f \in D^m\ \sigma(f) = (\sigma(f))_{f_i} \text{ for } 0 < i \leq m\}$$

Notice that we might have used $(S^n)^{D^m}$ itself, and that we might have restricted this set of theoretically possible information states to the set of proper states which is presently defined, and which force (situated) information states to acknowledge the existence of the individuals they are confronted with. These informational objects *appear* to be rigid in conversation and information exchange, because interpretation is always defined pointwise over the possible instantiations of our information states, the tuples of objects relative to which interpretation takes place. In actual interpretation, there is only one real and definite tuple of demonstrable objects. But the fact that especially *that* tuple of objects makes up the tuple of demonstrable objects, is not something which is determined by the information states at issue. For this reason, we also have to generalize our earlier notions of support and acceptance:

Definition 8 (Global Support and Acceptability) Let $\sigma \in \Sigma^{m,n}$, then:
σ supports ϕ wrt. M and g iff $\forall f \in D^m\ \sigma(f)$ supports ϕ wrt. M, g and f

σ accepts ϕ wrt. M and g iff $\exists f \in D^m$ $\sigma(f)$ accepts ϕ wrt. M, g and f

It may be clear that these global notions of support and accetability are motivated by a global interpretation function $\sigma[\![\phi]\!]_{M,g}$, which can be defined by $\sigma[\![\phi]\!]_{M,g}(f) = \sigma(f)[\![\phi]\!]^f_{M,g}$. Here, $\sigma[\![\phi]\!]_{M,g}$ is the global information state that results from updating global state σ with ϕ. It may also be noticed that our global notions are simply defined in terms of the situated ones, and that, thus, all our earlier observations about $\sigma(f)[\![\phi]\!]^f_{M,g}$ equally apply to $\sigma[\![\phi]\!]_{M,g}(f)$. In other words, our update logic remains entirely the same. All that has changed is that we have allowed for the possibility of partial information about the identity of demonstrable objects. And having done so, we are allowed to, as it were, carry our information states across different situations, and now we can give sensible descriptions of changes of states which correspond to changes of situation. Two types of change are of special interest to us, both of which are actually involved in our example above. The first involves the transition of an object into a subject, the second involves the encountering, and identifying, of objects.

The formally trained reader may already have noticed that, according to our definition of global information states, there is at most some typological difference between objects and subjects. Objects can be subjectified and subjects objectified without any loss of information:

Definition 9 (Subjectification and Objectification) Let $\sigma \in \Sigma^{m,n}$
for $0 < i \leq m$, the subjectification of the i-th object is $\sigma^{\uparrow i} \in \Sigma^{m-1,n+1}$:

$\forall f' \in D^{i-1}$, $f'' \in D^{m-i}$: $e \cdot d \in \sigma^{\uparrow i}(f' \cdot f'')$ iff $e \in \sigma(f' \cdot d \cdot f'')$

for $0 < j \leq n$, the objectification of the j-th subject is $\sigma^{\downarrow j} \in \Sigma^{m+1,n-1}$:

$\forall w \in W$, $e' \in D^{j-1}$, $e'' \in D^{n-j}$: $w \cdot e' \cdot e'' \in \sigma^{\downarrow j}(d \cdot f)$ iff $w \cdot e' \cdot d \cdot e'' \in \sigma(f)$

(In fact, there is a one to one correspondence between states of information about n subjects and states of information about n objects. If ϵ is the empty tuple, then, for $\sigma \in \Sigma^{n,0}$ the corresponding state $\tau \in \Sigma^{0,n}$ is defined by $\tau(\epsilon) = \{w \cdot f \mid w \in \sigma(f)\}$, and for $\tau \in \Sigma^{0,n}$ the corresponding state $\sigma \in \Sigma^{n,0}$ is defined by $\sigma(f) = \{w \mid w \cdot f \in \tau(\epsilon)\}$.) Speaking from intuition, only transitions in one direction seem to make sense: the subjectification of objects. The subjectification of an object is our formal analogue of the phenomenon of losing track of an object. If one loses track of, say, the i-th object of an information state, it is turned into its first subject. If σ had embodied the information that the specific heavenly body referred to with $\mathtt{d}_i$ is Hesperus, and that it is a planet, then $\sigma^{\uparrow i}$ embodies the information that its first subject is a planet, viz., Hesperus. And, although state σ can be said to support the statement that Hesperus is the object that actually was pointed at with $\mathtt{d}_i$, relative to an actual case $f \in D^m$, there need not be any such similar way in which σ' can be said to support something like that. What is lost in $\sigma^{\uparrow i}$ is precisely the 'apparent' connection with the individual which has been subjectified.

Although one might at first glance be inclined to conceive of the recognition of an object as being modeled by our notion of a subject's objectification, this would be quite counterintuitive indeed. Subjects simply don't walk out of their stories and say 'Hello!' to you. (Although it *may* be that people under hypnosis can be made to think so.) What normally happens in the recognition of an object is that one runs into an object and that one next identifies the object with a previously introduced subject, but that is something entirely different. What happens then, like what happens in the recognition of Hesperus every night, is that one is confronted with an object, obviously dressed with those properties that enable you to identify the object with one of the subjects of your information state. In order to account for this, we need to to say first what it means to encounter an object:

Definition 10 (Encountering Objects) For $\tau \in \Sigma^{m,n}$ the update of τ with one object is the state $\tau^{+1} \in \Sigma^{m+1,n}$ such that $\tau'(f \cdot d) = (\tau(f))_d$

The mere confrontation with an object brings about an extension of the sequence of demonstrable objects with possible individuals which are acknowledged to exist. Of course, you normally gain more information about an encountered individual, for instance, by observing the most obvious properties of that individual (type of individual, location, etc. etc.). In order to elaborate upon this a little further, suppose you are in the jungle, and for all you know, Dr. Livingstone, a man you have never met, but also a man whom you have heard a lot about and whom you respect most, is the only man hanging around there. (It is supposed you are a woman.) Then, clearly, on meeting another man in that jungle, you cannot but conclude that that is Dr. Livingstone ("Dr. Livingstone, I presume?"). Like we said, this does not mean that you had an encounter with a subject. You encountered an object, and you were able to identify him with the subject Dr. Livingstone. In our system, this situation is formally rendered as follows. Assume you are a woman, suppose your state of information $\sigma \in \Sigma^{m,1}$ before the encounter in the jungle has Dr. Livingstone as its only subject, and supports that Dr. Livingstone is the only man in the jungle. (For any sequence $f \in D^m$, we simply assume that $\sigma(f)$ encodes the information that the individuals in f are real wild beasts threatening you right now, something which is ignored below.) So, σ is a function such that for $f \in D^m$:

(11) if $\langle w, d\rangle \in \sigma(f)$ then $d = F_w(l)$ & $F_w(MiJ) = \{d\}$

Now the situation changes. An individual approaches and you notice it. That is to say, your state is confronted with an object, and the result is the function σ' defined by:

(11′) $\sigma'(f \cdot d') = \{e \in \sigma(f) \mid d' \in D_{w_e}\}$

You next take notice of the alleged fact that this individual is a man in the jungle. The resulting state is σ'', as defined by:

(11″) $\sigma''(f \cdot d') = \{e \in \sigma(f) \mid d' \in D_{w_e} \;\&\; d' \in F_{w_e}(MiJ)\}$

A little calculation shows that this comes down to the following:

(11‴) $\sigma''(f \cdot d') = \{\langle w, d\rangle \in \sigma(f) \mid d = d'\}$

In fact, this is your old information state updated with the information that the object you find yourself confronted with is Dr. Livingstone, precisely like we want it to be. On the basis of your information you have identified the individual you encountered.

The case of our agent Herman can now be, concisely, put as follows. Let us just assume there are four possible worlds (left), w, w', v and v', each of them with the same domain $\{d, d'\}$. In w Phosphorus is d and Hesperus is d', in w' it's the other way around, in v both are d, and in v' both are d'. Herman's afternoon information state $\sigma \in \Sigma^{0,2}$ is a state about no objects and two subjects, Phosphorus and Hesperus, respectively. It is (completely) characterized as follows:

(12) $\sigma(\epsilon) = \{\langle w, d, d'\rangle, \langle w', d', d\rangle, \langle v, d, d\rangle, \langle v', d', d'\rangle\}$

In the morning, Herman is confronted with an object which he recognizes as Phosphorus. His state $\sigma' \in \Sigma^{1,2}$ is then characterized by:

(12′) $\sigma'(d) = \{\langle w, d, d'\rangle, \langle v, d, d\rangle\}$
$\sigma'(d') = \{\langle w', d', d\rangle, \langle v', d', d'\rangle\}$

Herman's state σ' supports $\mathtt{this}_1 = \mathit{Phosphorus}$, and it accepts both $\mathtt{this}_1 = \mathit{Hesperus}$ and $\mathtt{this}_1 \neq \mathit{Hesperus}$. If the first object of Herman's state σ' is subjectified, with a state in $\Sigma^{0,3}$ as a result, we may safely assume that Herman is so smart as to merge the (identified) first and third subject, and thus he gets back in his afternoon state σ. In the evening, Herman is confronted with an object which he recognizes as Hesperus. His state $\sigma'' \in \Sigma^{1,2}$ is then given by:

(12″) $\sigma''(d) = \{\langle w', d', d\rangle, \langle v, d, d\rangle\}$
$\sigma''(d') = \{\langle w, d, d'\rangle, \langle v', d', d'\rangle\}$

Herman's state σ'' supports $\mathtt{this}_1$ *Hesperus*, and it accepts both $\mathtt{this}_1 = \mathit{Phosphorus}$ and $\mathtt{this}_1 \neq \mathit{Phosphorus}$. In short, although Herman appears to be very good in recognizing Phosphorus as Phosphorus in one situation, and Hesperus as Hesperus in another, his state never reaches the momentum by which it supports either that Hesperus is Phosphorus, or that Hesperus is not Phosphorus. Sofar, the relevant facts in each situation are as we have assumed them to be in the preceding section in our situated update logic, the main difference being that we can conceive of an information state as carrying information from one situation to another.

To conclude this section, we discuss a small, but subtle, difference between our global and situated notions of support, which has to do with the identity of objects. We have seen above that given a definite parameter of contextually supplied individuals, there is no doubt about the question as to which of these are distinct from one another. Relative to such a parameter $f \in D^m$, a situated information state s which at least supports the existence of the individuals in f, will be such that it supports $\mathtt{d}_i = \mathtt{d}_j$ if f_i is f_j, and if f_i is not f_j it will support $\mathtt{d}_i \neq \mathtt{d}_j$. In our global perspective, this is no longer true. One and the same global information state σ may just as well accept any one of $\mathtt{d}_i = \mathtt{d}_j$ and $\mathtt{d}_i \neq \mathtt{d}_j$ without being absurd itself. (That is, for some f such that f_i is f_j, and some f' such that f_i is not f_j, it may be that $\sigma(f)$ and $\sigma(f')$ are both non-absurd states.) To be sure, this means that our system with global information states allows for the possibility that an information state is given two objects which may turn out to be the same. One might argue that we have to exclude this possibility, reasoning, roughly, as follows: "Well, look. If I point at an object, and then at another object, then there cannot be much doubt that these are two different objects, isn't it? And if I point at one and the same object, I hope you wouldn't be inclined to doubt that it is one and the same object? So, what can there be more than just the issue whether I am or whether I am not pointing at one and the same object twice?"

Now, this can be admitted, that if you acknowledge the objects of pointing to be different—that is, if you have information that they are different—then they are different, of course. But the acknowledgement of this difference figures as some kind of hidden assumption in an argument of the kind sketched above, which purports to establish the self-evidence, say, of the difference of two demonstrable objects. Either two acknowledged to be different objects are raised in the air and the audience is requested to contemplate the possibility of the two being the same object; or, there are *stipulated* to be two different objects and then the reader is asked to judge the acceptability of statements asserting the identity of the two. In any case, one starts out with the apparent difference of two objects. So, what the above argument shows is not much more than the fact that if your information excludes that a is identical to b, than it is unacceptable for you to hear that, in addition, a maybe also is not identical to b. But that does not settle the case whether it is possible, as it still is in our system, that one appears to be confronted with two objects, but which are not apparently excluded to be a different individual.

In the first place such borderline situations seems to be possible in a certain abstract sense. For instance, one can have a simultaneous conception of our morning and evening sessions, timelessly conceived, as, for instance, a kind of 'meet' of the Phosphorus and Hesperus situation. (For expository purposes we do represent such situations, for instance by dividing a blackboard in two and sketching the morning sky on the left half, and the evening sky on the right half.) If such a situation can be conceived to be real, then it constitutes a prime example involving two demonstrable heavenly bodies which may turn out to be identical.

But also in more daily situations one's perceptual apparatus may be not sufficient to settle the identity of perceived objects. The cat you have been hearing caterwauling for hours upon the terrace, and that animal the shady contours of which you have been watching all that time, well, *they* might be identical, and different, wouldn't they? Or take this situation. You are looking through two doors next to each other. Behind the right door you see a man on his back, and behind the left door you see a man en profil. In this case it might be that you are watching two men, one in each room. But it is equally possible that the two doors give access to one room, and that you are looking, through the left door, into a mirror which shows you en profil the man you are watching through the right door on the back. Now, although our language is not particularly well fit two talk about the *two* individuals possibly being *one*, it may occur to you that it is both acceptable that the man behind the left door is the man behind the right door, and that they are not. Like in Kripke's description of the Hesperus/Phosphorus case, which we have quoted above, the point is that in case there *is* a mirror, and in case there is *no* mirror, your epistemic state would be qualitatively the same anyhow. And the point is that if there is a mirror, which you can't tell, then the two 'objects' which you can refer to are identical, and if there is no mirror, which you can't tell either, they are distinct. In other words, and in either case, your epistemic state does not exclude that the first object is identical to the second, nor that they are not. And this is precisely what can be modeled with our global, epistemic, notion of information.

4 On Aboutness

In the preceding section we have generalized our notion of information in order to accomodate an observed gap between epistemological and ontological aspects of direct or demonstrative reference. But, accomodating such a gap in an *epistemic* semantics may appear to imply that the ontologistics starts to escape us completely. Apparently, we will also have to say something about how to bridge the gap. After having detached the individuals we have information about from the information we have about them, we will now turn to the question how we should conceive of this 'aboutness' relation, and say when an information state supports certain information about a certain individual. This section, then, is devoted to the notion of, as we will call it, 'de re support'.

In as much as we have been taking pains to detach the individuals from the information we have about them, we also think that in fact it is them which our information is about, this in a non-trivial sense. Following, for instance, Kripke and Kaplan, we think that it is these individuals that concern us in thinking and speaking in the first place, and any statement or thought about Hesperus must be taken to be one about Hesperus under whatever guise. As our agent Herman would, or should, agree, if he believes that there is a homunculus living on that very planet which is dubbed 'Phosphorus' in the morning, his belief also holds for that very same planet in the evening, no matter whether Herman knows how to identify Phosphorus in the evening. So, although Herman need not agree with us when we point at Phosphorus in the evening and say that Herman believes that `that` is a planet where a homunculus lives, still it is true of the planet—on the assumption that what we are referring to actually *is* Phosphorus—that Herman holds the belief reported. Keeping to the assumption mentioned, it holds true that, about that specific planet, Herman believes the thoughts that it is Phosphorus, that it has a homunculus living on it, and maybe even also that it is not Phosphorus (for instance, when looking at it in the evening). This situation is essentially similar to the one reported in Quine 1956. There, the protagonist Ralph has gathered information both about a certain man in a brown hat glimpsed under questionable circumstances, a man which he believes to be a spy, as well as about a grey-haired man known as a pillar of the community, a man which Ralph believes not to be a spy. It turns out that the two are one and the same person, Bernard J. Ortcutt. About Ortcutt, Ralph believes that he is a spy, and that he is not a spy, although he needn't believe that this Ortcutt is both a spy and not a spy, of course.

The interesting point about examples like these is that the relevant situations and information states can be modeled fairly easily. We will not bother to give a definition of the update of information states with de re attitude reports, but confine ourselves to a (preliminary) definition of a (meta-theoretical) notion of de re support (this, in order to keep things tractable). There are three ingredients to a specification of the notion of de re support. It refers to an information state σ, a world w together with its domain D_w, and, what we will call, a 'history' A of σ in w. The information states we may assume to be about zero objects. The notion of aboutness we are after may derive from objects that have been encountered, but the objects may have been subjectified without this subjectification in any way threatening their 'abouthood'. The world is assumed to be the actual world, relative to which the information state can be said to be about its aboutees. The so-called 'history' A summarizes what must be conceived of as the relevant facts about σ in w. If the information state has ever witnessed an encounter with an individual d, then it has had an object which has actually been instantiated by d, and which may have turned into a subject which we want to claim to be about d. A history, according to this view, is a set of anchors, which relate subjects of σ with individuals in D_w. (As a matter of fact, we may want to generalize the definition to be presented shortly in two ways. In the first place, objects are, of course, also about individuals in the most obvious sense. In the second place, an anchor must be conceived of as relating not one subject with one individual at a time, but a sequence of subjects with a sequence of individuals. For the present purposes, however, we may stick to the singular cases.)

We now turn to the definition of the support-of relation. We will use the following locution. We will say that an information state does (or does not, for that matter) support a formula with a distinguished free variable in it of a certain object. If x is the variable at issue, we use $\phi(x)$ to indicate the formula, and we use $\phi(t)$ to indicate the formula obtained from $\phi(x)$ by substituting all free occurrences of x by t. The most easy way to define our notion of de re support employs demonstratives to refer to anchored subjects which we objectify. (It is assumed that $\phi(x)$ contains no demonstratives itself.) We then can say that an anchor a anchors a state σ to d by τ, $a(\sigma, d, \tau)$, iff the i-th subject of σ is anchored by a to d, and τ is the objectification $\sigma^{\downarrow i}$ of σ's i-th subject. The required notion of support now can be put as follows:

Definition 11 (De Re Support) σ supports $\phi(x)$ of d wrt. M, w and g iff

$$\exists a \in A_w \text{ such that } a(\sigma, d, \tau) \text{ and } \tau \text{ supports } \phi(\mathtt{d}_1) \text{ wrt. } M \text{ and } g$$

Before we turn to some applications of the present definition, it may be expedient to point at the internal existential quantification over anchors in the definition of de re support. The internal quantifier blocks both negation exportation and conjunctive closure of de re beliefs. And for this reason, our analysis is structurally the same as the analysis of de re beliefs presented in Kaplan 1969. There, these unwanted inferences are also blocked by an internal existential quantifier. The difference is in what is in fact quantified over. In Kaplan's original proposal we find quantification over very special kinds of representation. In our proposal anchors are quantified over, which are simple records of the facts that specific aboutness relations exist.

Let us now return to Ralph's beliefs about Ortcutt. Apparently, his state of information is about a number of subjects, one—say, the i-th—of which is ascribed the properties Ralph has observed the suspectly behaving man in a brown hat to have, another—say, the j-th—the properties of a prototypical pillar of the community. The first is the subjectified version of an object Ralph has had an encounter with, and which, as a contingent matter of fact, actually was Bernard J. Ortcutt; the second we may as well conceive of as being constructed from hear-say, and watch-television, and, as another contingent matter of fact, as being in fact instantiated by this very same Bernard J. Ortcutt. So, as a matter of fact, there are two anchors, one of which maps Ralphs' i-th subject onto Ortcutt, and another which maps Ralph's j-th subject onto Ortcutt. Given this much, and given Ralph's belief that his i-th subject is a spy, and his belief that his j-th subject is not a spy, the following de re claims hold of his state σ:

(13) σ supports $spy(x)$ of Ortcutt and σ supports $\neg spy(x)$ of Ortcutt

Still, as long as Ralph's state is not inconsistent, Ralph's state does not support a contradiction

(14) σ does not support $(spy(x) \wedge \neg spy(x))$ of Ortcutt

Clearly, the situation, and the beliefs ascribed, are as Quine had originally presented them. However, a substantial difference with Quine's proposal is that our analysis of the whole situation is cast in terms of an independently motivated notion of information state, and a rather natural notion of aboutness, whereas Quine's analysis employs unanalyzed relational notions of belief. (Putting it differently, one may as well say that our proposal *is* an analysis of Quine's relational notion of belief.) Following up on an observation in Kaplan 1969, we also find that the fact that σ supports $\neg spy(x)$ of d does not entail that σ does not support $spy(x)$ of d. And this is correct, for, apparently, in the above situation we find that σ supports both $\neg spy(x)$ of d and $spy(x)$ of d. There is nothing contradictory about that. Summing up, we find more in general that:

Observation 9

1. σ may support $\phi(x)$ of d and $\psi(x)$ of d and not support $\phi(x) \wedge \psi(x)$ of d
2. σ may both support $\phi(x)$ of d and $\neg\phi(x)$ of d

One last observation we can make concerning Ralph is this. It may be the case that Ralph knows that this grey pillar of the community, his j-th subject, is called 'Ortcutt'. If this is so, then it follows from the fact that his state supports that Ortcutt is not a spy, that his state supports of Ortcutt that he is not a spy. But even then, from the fact that his state also supports of Ortcutt that he is not a spy, it does not at all follow that his state supports that Ortcutt is not a spy. More in general we find that:

Observation 10 If σ supports $x = a$ of d, then

1. if σ supports $\phi(a)$, then σ supports $\phi(x)$ of d, but
2. if σ supports $\psi(x)$ of d, then it need not be that σ supports $\psi(a)$

And, apparently, this is as we should want it to be.

For a final illustration of our notion of de re support, let us look in a little more detail at Herman's information about Hesperus and Phosphorus.

We assume he is in his afternoon state which is presented above, that is, in state $\sigma \in \Sigma^{0,2}$ about no objects and two subjects, Phosphorus and Hesperus, respectively:

(12) $\sigma(\epsilon) = \{\langle w, d, d' \rangle, \langle w', d', d \rangle, \langle v, d, d \rangle, \langle v', d', d' \rangle\}$

The actual weorld is assumed to be v, and both his first and his second subject are assumed to be anchored to Venus in v, that is, to d (which is both Phosphorus and Hesperus). In virtue of this, Herman's state licenses the following de re supports:

(15) σ supports $x = \textit{Phosphorus}$ of d
σ supports $x = \textit{Hesperus}$ of d

But Herman's state does not support what we know:

(16) σ does not support $(x = \textit{Phosphorus} \wedge x = \textit{Hesperus})$ of d

since, clearly, σ does not support $\textit{Phosphorus} = \textit{Hesperus}$. We can even think that Herman, mistakenly, comes to believe that Hesperus is *not* Phosphorus. His state σ' would then be given by:

(17) $\sigma'(\epsilon) = \{\langle w, d, d' \rangle, \langle w', d', d \rangle\}$

This state, under the circumstance mentioned, would license the following de re supports

(18) σ' supports $x = \textit{Phosphorus}$ of d
σ' supports $x \neq \textit{Phosphorus}$ of d
σ' supports $x = \textit{Hesperus}$ of d
σ' supports $x \neq \textit{Hesperus}$ of d

without being inconsistent. The first and the fourth de re supports can be conceived to be dawn reports. In the morning, Herman has identified an object, which as a matter of fact is d, with his first subject, Phosphorus. In virtue of the associated anchor, his information supports that that object is Phosphorus and not Hesperus. The evening before, Herman had identified an object, which as a matter of fact was d as well, with his second subject, Hesperus. In virtue of that situation, Herman's state supports that the same individual d is not Phosphorus, but Hesperus, of which the second and third clause of 18 bear witness.

5 Concluding Remarks

It is time we take stock. we have progressively developed a model-theoretic notion of information about subjects and objects. Subjects originate from hearsay, so to speak, objects are provided by the immediate (non-)linguistic context. Both are partial objects. About the properties and identity of subjects and objects we normally have partial information only. The difference between the two derives from the fact that interpretation takes place in context, that is, with respect to a sequence of objects which are assumed to be identified. In the picture that has evolved in this paper, the difference between subjects and objects is of a typological nature only. And, in fact, we might even do away with that. Of course, there is a vast difference between the two types of beings, but if we are only concerned with modelling the contents of our partial information states, there need not be a principled difference. The fact that objects are typically present as sources of information only makes them different from subjects in a principled way if information states are conceived of as states of agents who collect information from their environments. That is, they will be seen to be different kinds of beings if we also want to take into account the interaction between information, causation, action and perception. And, of course, that interaction *is* a highly interesting subject of study, but it simply is not the present one. One might as well think that objects, and not subjects, are or can be attributed special kinds of properties, for instance, concrete perceptually observable properties, which also uniquely relate them to the observer. And this may also be very true, but again it need not concern us here. For all of our semantic concerns sofar, we can do away with any epistemic difference between subjects and objects. We can conceive of all of them as subjects, and qualify a certain subset of them as what by a contingent matter of fact are objects. And if we do so, then we can even come to a very simple, but comprehensive, picture of situations of information exchange.

In such a final picture the central concept is that of a relation in intension, modelled as a set of cases. These n-ary relations are both models of information states about n subjects, as well as of exchange situations with n objects. If one wants, one may also say they are structured propositions, in which a number of 'individuals' are 'trapped'. A 0-place relation is just a set of possible worlds, i.e., a proposition in the old sense; for $0 < n$, the notion of a n-place relation is just a Lewisian generalization of Lewisian propositions, which are 1-place properties. (Cf., Lewis 1979. As a matter of fact, we might feel compelled to exclude information states about 0 subjects, and assign a special role to the first subject of any information state, viz., as that of the information state's self. This would give us a proper way of dealing with the difference between de re attitudes involving oneself, and de se attitudes, cf., Kaplan 1978; Lewis 1979; Perry 1979. I will skip over this issue here, though.) An exchange situation t is properly thought of as a part of the real world, and its n subjects must be taken to approximate the real individuals which are actually present. So, if w is the actual world, then there are individuals $d_1, \ldots, d_n \in D_w$ and such that $\langle w, d_1, \ldots, d_n \rangle$ is a possibility of t. The exchange situation must also be taken to be the 'obvious' exchange situation, that is, the common ground of the exchange partners. Since t figures as the common ground, we will conceive of the states s of the participants as updates of t. Thus, for any two participants there are information states s and s', and such that $t \leq s, s'$, and the first n subjects of s and s' must be conceived to be (factually) linked, and (demonstratively) anchored to the real individuals $d_1, \ldots, d_n$. Other subjects of s and s' can be factually linked, in virtue of current or preceding exchange. Information and exchange of information can be said to be about certain individuals in virtue of factual anchors and it can also be said to be about certain subjects in virtue of factual links. Interpretation, basically, remains as it has been defined in this paper. End of the picture.

At the present moment, the most interesting thing to conclude maybe should be the following. It need not be too surprising that the notion of information we started out with (partial information about partial entities in discourse) also serves well in accounting for partial information about (the identity of) real individuals. But what we take to be quite positively indeed, is that on our way of modeling it, this kind of information can be used in an analysis of de re attitude descriptions which perfectly fits the observations made of Quine and Kaplan. To this end, we are in no need of some stipulatively introduced relational or representational notions of belief. Together with the observed facts about aboutness, the developed notion of information fully suffices.

As for a final remark, it would be interesting to compare the model-theoretic way of modeling information advocated here with discourse representation theoretic and situation theoretic approaches. Unfortunately, this must be left for another occasion. We just leave it at the mere observation that our anchors bear close resemblance to the anchors used in several versions of *DRT*, and in the situation theoretic 'frame of mind' theory of belief and belief reports (cf., for instance, Kamp 1990; Barwise and Perry 1983; Cooper 1994). Despite the resemblances, however, there must be structural differences.

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