# Monsters begat by quantifiers?

Fabio Del Prete, Alessandro Zucchi

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Fabio Del Prete
CNRS Lab CLLE-ERSS
Toulouse

Sandro Zucchi
Dipartimento di Filosofia
Università degli Studi di Milano

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**Abstract**

It is common practice in formal semantics to assume that the context specifies an assignment of values to variables and that the same variables that receive contextually salient values when they occur free may also be bound by quantifiers and $\lambda$s. These assumptions are at work to provide a unified account of indexical and bound uses of third person pronouns, namely an account by which the same lexical item is involved in both uses. One apparent consequence of this approach is that quantifiers and $\lambda$s are monsters in Kaplan's sense. We argue that this consequence can, and should, be avoided. We explore an alternative unified account based on the idea that variable assignments occur both as coordinates of the context and as coordinates of the circumstance of evaluation. The outcome is a non indexical account of free third person pronouns and a new conception of the role and structure of assignment functions.

## 1 A common practice and its consequence

It is common practice in formal semantics to assume that (i) context specifies, among other pieces of information, an assignment of values to variables. This assumption is invoked, for example, in the semantic analysis of Hittite relative clauses (Bach and Cooper 1977), deictic pronouns (Kaplan 1989, Heim and Kratzer 1998) and so-called "unarticulated constituents" (Stanley 2000). All these analyses assume that Logical Forms (LFs) of natural language sentences may contain free variables whose values are contextually provided. It is also customarily assumed that (ii) the variables that receive contextually salient values when they occur free may be bound when they occur in the scope of quantifiers and $\lambda$s bearing the same index.

While some of the linguistic phenomena that are so analyzed also admit alternative accounts that make no reference to variables of this kind, in the case of third person pronouns a powerful reason for making these assumptions is that they allow one to account for their bound and indexical occurrences by supposing that the same lexical item is involved. According to this view, for example, (1) and (2) contain the same lexical item "he$_i$", whose denotation depends on a variable assignment (although the semantics of "every" requires one to consider alternative assignments to determine truth):

(1) He$_i$ is intelligent.

(2) Every student$_i$ thinks he$_i$ is intelligent.

Since, in English and in several other languages, third person pronouns that occur free are not phonologically distinct from third person pronouns that occur bound, it is clearly desirable to adopt a uniform semantic account, which is what assumptions (i)-(ii) above allow us to do.

If one analyzes third person pronouns in this way, a natural move (one which, for example, Heim and Kratzer seem to agree on) is to regard the variable assignment involved in spelling out the interpretations of the quantifiers and the $\lambda$-operator as a *contextual coordinate*. If this move is made, the semantic clause for universally quantified formulae should have form (3), where $c_g$ is the variable assignment of the context $c$:

(3) $[\![\forall\nu\varphi]\!]_{M,c,w,t} = 1$ iff $[\![\varphi]\!]_{M,c',w,t} = 1$ for every $c'$ such that $c'_g$ differs from $c_g$ at most for the value that $c'_g$ assigns to $\nu$ and $c'$ agrees with $c$ on all other coordinates.

The semantic clause for the $\lambda$-operator should be stated along similar lines:

(4) $[\![\lambda\nu\varphi]\!]_{M,c,w,t}$ = the function $f$ from the domain D of M to $\{0,1\}$ such that for every $a \in$D, $f(a)$=1 iff $[\![\varphi]\!]_{M,c',w,t} = 1$, where $c'$ is such that $c'_g$ assigns $a$ to $\nu$ and assigns the same values as $c_g$ to all other variables, and $c'$ agrees with $c$ on all other coordinates.

As Rabern (2012) points out, one consequence of this way of stating the semantics of quantifiers is that they are Kaplanian *monsters* (Kaplan 1977). Indeed, the universal quantifier in (3) meets Kaplan's definition of monster, by which a monster is any operator $O$ such that $[\![O\varphi]\!]_{M,c,w,t}$ depends on $[\![\varphi]\!]_{M,c',w,t}$, for some $c' \neq c$. For the same reason, the $\lambda$-operator in (4) also qualifies as a monster.

## 2 Reasons to beware

The proposal we just outlined is summed up in (5):

(5) a. variable assignments are contextual coordinates,
b. the interpretations of the universal quantifier and the $\lambda$-operator are spelled out as in (3)-(4).

It is clear that, if one takes step (5), monsters are much more widespread in natural languages than one might think. In addition to languages displaying shifted indexicals corresponding to "I", "you", "here", and "yesterday" (Schlenker 2003, Anand and Nevins 2004), which initially fueled the supposition that monsters do exist in natural languages, quantifier binding and constructions that make use of the $\lambda$-operator would also involve monsters. By itself, this is no objection to (5). After all, theoretical analyses of linguistic phenomena may very well uncover that apparently unrelated facts involve the same underlying linguistic operation. However, the fact that step (5) involves a radical reclassification of the types of constructions that contain monsters should make us wonder whether the linguistic data really support the step or other alternatives are available.

To see how radical a step (5) is, consider (1)-(2) again:

(1) $\text{He}_i$ is intelligent.

(2) Every $\text{student}_i$ thinks $\text{he}_i$ is intelligent.

In view of the fact that (2) contains the pronoun "he", which acts as an indexical in (1), one may be tempted to accept the consequence that (2) is a case of indexical shift after all, hence a monster. But now consider (6):

(6) John saw every man.

According to some, the interpretation of (6) is achieved by raising the quantified NP "every man" to get a structure in which the quantified NP binds the trace left behind by raising:

(7) $[\text{Every man}]_i$ John saw $t_i$

If "every" in (7) is interpreted as involving a quantification over contextual assignments like "$\forall$" in (3), the consequence is that (6) is a case of context shift, thus a monster. But (6), unlike (2), contains no expression that is indexical or ever behaves like one! Of course, one might claim that the interpretation of "every" in underlying LFs like (7), unlike the interpretation of "every" in the LF of (2), is not given by a clause like (3). However, this would involve positing different devices to interpret the universal quantifications in (6) and (2). It would involve, moreover, interpreting (6) and (8) by quantifying over contexts in (8) but not in (6):

(8) Every man$_i$ is such that John saw him$_i$.

We take it that, other things being equal, such a consequence would be undesirable. Thus, taking step (5) plausibly leads one to the radical conclusion that (6) is monstrous.

So far, we only have a reason for caution in taking step (5) (it's a reason against it only if one is not willing to accept (6) as a case of context shift). Here is a reason that advises against taking the step. Let's ask: what is a context? Lewis (1980) characterizes the difference between contexts and indices (or contexts and circumstances of evaluation, in Kaplan's terms) in this way:

> A *context* is a location – time, place, and possible world – where a sentence is said. It has countless features, determined by the character of the location. An *index* is an $n$-tuple of features of context, but not necessarily features that go together in any possible context. Thus an index might consist of a speaker, a time before his birth, a world where he never lived at all, and so on. Since we are unlikely to think of all the features of context on which truth sometimes depends, and hence unlikely to construct adequately rich indices, we cannot get by without context-dependence as well as index-dependence. Since indices but not contexts can be shifted one feature at a time, we cannot get by without index-dependence as well as context-dependence. (Lewis 1980, pp. 31-32).

According to this view, contexts are not abstract collections of features which can be shifted one at a time, they are possible locations where a sentence is uttered. Because of this, a context has an agent that utters the sentence at a certain time in a certain place, and therefore exists at that time and place. Now, suppose $c$ is a context in which agent $a$ utters sentence $S$ at the time $t$ and place $p$ in the world $w$. There is no such thing as a context which is exactly like $c$ except that the agent is $b$ instead of $a$. If you change the agent that utters $S$ at $t$ in $p$, you change the world as well. This is why contexts, unlike indices, cannot be shifted one feature at a time. This notion of context underlies Kaplan's (1977, 1979) treatment of indexicals, in particular motivates his constraints on contexts, which are central for the logic of the indexicals "I", "here", and "now", like the one requiring that the speaker of a context be located at the place of the context in the world and time of the context.

Now, let's consider again assumption (5-a). If contexts are not abstract collection of features, what does it mean to claim that variable assignments are contextual coordinates? A plausible answer is this. A location where a sentence is uttered, besides being part of a world and including an agent who utters it at a certain time $t$ and place $p$, may include certain referential intentions by the agent, possibly manifested by pointings or other gestures, which fix the referents of demonstrative expressions occurring in the sentence. In this sense, introducing variable assignments as contextual coordinates is simply a way of representing these collections of contextual cues that accompany the utterance of demonstratives and contribute to fix their referents. Suppose this picture is correct. Then, given a context $c$ there is no such thing as a context where the variable assignment differs from that of $c$ and which agrees with $c$ on all other coordinates. If you change the variable assignment, you change the referential intentions and pointings of the agent that utters $S$ at $t$ in $p$, thus you change the world as well. But then, (3) is incorrect as it stands. And, if we revise (3) by letting the world change, we predict incorrect truth-conditions for (8), since what is relevant for the truth of (8) is whether every man is such that John saw him in the world of the context and not in other worlds in which the referential intentions and demonstrations of the speakers are different. While this is no conclusive argument against treating quantifiers as monsters, it poses a challenge for a theory that treats quantifiers that way: such a theory should provide a plausible formulation of how quantifiers make the context *as a whole* shift which delivers the desired semantics for quantifiers.

To sum up, the above considerations give reasons to be cautious and perhaps avoid the step of regarding quantifiers and $\lambda$s as context shifters. If this step is to be avoided, however, how can we meet the challenge of providing a uniform semantic account of third person pronouns? What follows is an exploration of a possible avenue.

## 3 Doubling the assignment

Kaplan's semantics, more precisely some suitable extension of it, allows one to assign truth-conditions to natural language sentences containing indexical third person pronouns, and more generally demonstrative expressions. Insofar as we regard this as one of the goals a semantics for natural languages should achieve, the reasons for regarding variable assignments as contextual coordinates are compelling: indeed, the reference of free third person pronouns depends on the context in which they are uttered.

Yet, (5-a) by itself does not entail that quantifiers are monsters:

(5) a. variable assignments are contextual coordinates.

In Kaplan's (1977) system, worlds and times are contextual coordinates: they are needed to account for the meaning of indexical operators like "it is actually the case that", "it is now the case that", and "yesterday". In the same system, modal operators and tenses require evaluating the sentence to which they apply relative to worlds and times different from those of the context. However, this does not qualify modal operators or tenses as monsters: worlds and times, besides being contextual coordinates, also belong to the circumstance of evaluation, and modal operators and tenses require us to evaluate sentences at different circumstances, not at different contexts. The same strategy may be used here to avoid treating quantifiers and the $\lambda$-operator as context shifters. The idea, in short, is this:

- denotation is relative to a context $c$ specifying a variable assignment $c_g$, and to a circumstance of evaluation including an assignment $g$, a world $w$, and a time $t$.
- Quantifiers and the $\lambda$-operator alike require evaluating the formulae to which they apply with respect to assignments minimally differing from $g$ (the assignment of the circumstance of evaluation).

This doesn't explain yet how the contextual assignment plays a role in fixing the reference of unbound third person pronouns. For this purpose, we need an additional assumption:

- a sentence is true in a context if it is true at the time, world, *and assignment* of the context.

Notice that we are departing here from the standard assumptions concerning propositions and truth in context. In possible world semantics, it is usually assumed that propositions are functions from world-time pairs to truth values. Hence, they are true or false relative to a world and a time, and the truth of a sentence S in a context $c$ is defined as truth of the proposition expressed by S in $c$ relative to the world and time of $c$. We assume instead that propositions are functions from worlds-times-assignments triples to truth values. Hence, they are true or false relative to a world, a time and an assignment, and the truth of a sentence S in a context $c$ is defined as above.

We present a formal system based on these ideas in section 4. Then, in sections 5-6, we turn to the semantics of third person pronouns and show how this system can account for their free and bound occurrences, and for their interaction with modal operators, by keeping true to the idea that quantifiers are no monsters and the semantic contribution of pronouns is uniform across their free and bound uses. In section 7, we raise an issue that we regard as *the funda mental problem* in trying to give a unified account of bound and free uses of third person pronouns. In section 8, we present a new version of the formal system designed to solve this problem. We sketch our proposal in two steps: first, we present a simple version of the theory to convey the intuitive idea underlying it, then we introduce some changes to improve its empirical coverage. We test the theory further in section 9. In section 10, we sum up the results of our inquiry. In Appendix 1, we state the formal system in its final form.

## 4 The language IL

**Symbols and formulae** An intensional language IL suitable for our purposes will include two types of individual variables, *plain* variables and *presuppositional* variables:

$x_1, x_2, x_3, \ldots$ (plain variables)

$x_1^m, x_2^m, x_3^m, \ldots$ (presuppositional variables)

$x_1^f, x_2^f, x_3^f, \ldots$ (presuppositional variables)

$x_1^n, x_2^n, x_3^n, \ldots$ (presuppositional variables)

Let $\mathcal{V}$ be the set of plain variables and $\mathcal{V}^*$ the set of variables (plain and presuppositional). Presuppositional variables will translate English third person pronouns. The language also includes an infinite number of $n$-place predicates (for any $n \geqslant 0$), the truth-functional connectives, the quantifier *every*, and the modal operators $\Box$, $\Diamond$. The definition of well-formed formula is done as usual for the truth-functional connectives and modal operators. If $\Phi$ and $\Psi$ are wffs and $\nu \in \mathcal{V}$, $\ulcorner every\ \nu\ \Phi\Psi \urcorner$ is a wff.

**Models** A model for IL is a structure $M =< \mathcal{C}, \mathcal{W}, \mathcal{U}, \mathcal{T}, \mathcal{P}, \mathcal{F} >$ such that

1. $\mathcal{C}$ is a nonempty set (the set of contexts), where if $c \in \mathcal{C}$,
   - (i) $c_a \in \mathcal{U}$ (the agent of $c$)
   - (ii) $c_t \in \mathcal{T}$ (the time of $c$)
   - (iii) $c_p \in \mathcal{P}$ (the position of $c$)
   - (iv) $c_w \in \mathcal{W}$ (the world of $c$)
   - (v) $c_g \in \mathcal{U}^{\mathcal{V}}$ (the assignment of $c$)
2. $\mathcal{W}$ is a nonempty set (the set of worlds)
3. $\mathcal{U}$ is a nonempty set (the set of individuals)
4. $\mathcal{T}$ is a nonempty set (the set of times)
5. $\mathcal{P}$ is a nonempty set (the set of positions)
6. $\mathcal{F}$ is a function that to every triple consisting of an n-place predicate $\mathtt{P}^n$, a world, and a time, assigns a set of $n$-tuples of members of $\mathcal{U}$.

The definition of model is similar to the one provided by Kaplan, except for the fact that a context also specifies an assignment to the plain individual variables (the elements in the set $\mathcal{V}$).

**Denotation** We assume that the denotation of an expression is relative to a model, a context of utterance, and a circumstance of evaluation consisting of a variable assignment, a world, and a time. We use "$[\![\alpha]\!]_{M,c,g,w,t}$" as short for "the denotation of $\alpha$ in the context $c$ relative to the circumstance $< g, w, t >$".

Variable assignments are total functions assigning an individual to each plain variable. The denotation of a presuppositional variable is determined by the value of the corresponding plain variable in this way:

(9) $[\![x_i]\!]_{M,c,g,w,t} = g(x_i)$.

(10) $[\![x_i^m]\!]_{M,c,g,w,t} = g(x_i)$ if $g(x_i)$ is human and male in $c_w$ at $c_t$, and it's undefined otherwise.

(11) $\left[\!\left[x_i^f\right]\!\right]_{M,c,g,w,t} = g(x_i)$ if $g(x_i)$ is human and female in $c_w$ at $c_t$, and it's undefined otherwise.

(12) $[\![x_i^n]\!]_{M,c,g,w,t} = g(x_i)$ if $g(x_i)$ is not human in $c_w$ at $c_t$, and it's undefined otherwise.

Notice that, according to (10)-(12), the definedness condition for presuppositional variables requires that the individuals they denote be of the relevant gender at the world and time of the context. We'll come back to this feature in sections 6-7.

The denotations of atomic formulae consisting of a predicate and the required number of variables are specified in this way (where $\nu_i \ldots \nu_j$ are variables, plain or not):

(13) Suppose $[\![\nu_i]\!]_{M,c,g,w,t}, \ldots, [\![\nu_j]\!]_{M,c,g,w,t}$ are defined.
Then $[\![\mathtt{P}^n(\nu_i, \ldots, \nu_j)]\!]_{M,c,g,w,t} = 1$ if $< [\![\nu_i]\!]_{M,c,g,w,t}, \ldots, [\![\nu_j]\!]_{M,c,g,w,t} > \in \mathcal{F}(\mathtt{P}^n)(w)(t)$;
$[\![\mathtt{P}^n(\nu_i, \ldots, \nu_j)]\!]_{M,c,g,w,t} = 0$ if $< [\![\nu_i]\!]_{M,c,g,w,t}, \ldots, [\![\nu_j]\!]_{M,c,g,w,t} > \notin \mathcal{F}(\mathtt{P}^n)(w)(t)$.

The clause for the denotation of universally quantified formulae is this (where "$g'[\nu]g$" is short for "assignment $g'$ differs from assignment $g$ at most for the value assigned to the variable $\nu$"):

(14) a. $[\![\textit{every}\ \nu\ \Phi\Psi]\!]_{M,c,g,w,t}$ is defined only if $[\![\Psi]\!]_{M,c,g',w,t}$ is defined for every $g'$ such that $g'[\nu]g$ and $[\![\Phi]\!]_{M,c,g',w,t} = 1$.
b. if $[\![\textit{every}\ \nu\ \Phi\Psi]\!]_{M,c,g,w,t}$ is defined, $[\![\textit{every}\ \nu\ \Phi\Psi]\!]_{M,c,g,w,t} = 1$ if $[\![\Psi]\!]_{M,c,g',w,t} = 1$ for every $g'$ such that $g'[\nu]g$ and $[\![\Phi]\!]_{M,c,g',w,t} = 1$; otherwise $[\![\textit{every}\ \nu\ \Phi\Psi]\!]_{M,c,g,w,t} = 0$.

According to (14), the quantifier "*every*" requires the nuclear scope $\Psi$ to be satisfied relative to assignments of the circumstance of evaluation that satisfy the restrictor $\Phi$. Thus, "*every*" is not a monster, since it does not require the context to shift.

**Truth in context** In Kaplan's original system, truth in a context is defined as truth at the circumstance that consists of the world and time of the context. Since we assume that circumstances of evaluation are triples consisting of an assignment, a world, and a time, truth in a context is defined as truth at the assignment, world, and time of the context:

$\Phi$ is true in a context $c$, in the model $M$, if $[\![\Phi]\!]_{M,c,c_g,c_w,c_t} = 1$,
$\Phi$ is false in a context $c$, in the model $M$, if $[\![\Phi]\!]_{M,c,c_g,c_w,c_t} = 0$

Let's now turn to the interpretation of third person pronouns.

## 5 The interpretation of third person pronouns

We follow Heim and Kratzer's (1998) view that the descriptive content of third person pronouns is presupposed and that the denotation of an expression is defined only if its presupposition is met.[1] We assume that occurrences of third person pronouns bear a referential index at LF. We translate "he$_i$", "she$_i$", and "it$_i$" as in (15):

(15) a. he$_i$ $\Rightarrow x_i^m$
b. she$_i$ $\Rightarrow x_i^f$
c. it$_i$ $\Rightarrow x_i^n$

The LF of (1) is now translated as (16):

(1) He$_i$ is intelligent.

(16) $intelligent(x_i^m)$

Notice that, by (10)-(12) above, the value of a variable that translates a pronoun is determined by the variable assignment of the circumstance of evaluation. However, by the definition of truth in a context we assumed, the value of the variable in (16) is identified with the value determined by the variable assignment of the context:

(17) a. $[\![intelligent(x_i^m)]\!]_{M,c,c_g,c_w,c_t}$ is defined
only if $[\![x_i^m]\!]_{M,c,c_g,c_w,c_t}$ is defined
only if $c_g(x_i)$ is human and male at $c_w, c_t$.
b. if $[\![intelligent(x_i^m)]\!]_{M,c,c_g,c_w,c_t}$ is defined, then:
"$intelligent(x_i^m)$" is true in $c$, in the model $M$,
if $[\![intelligent(x_i^m)]\!]_{M,c,c_g,c_w,c_t} = 1$
if $c_g(x_i)$ is human and male and intelligent in $c_w$,$c_t$.

Now consider (18):

(18) Every man$_i$ is such that he$_i$ runs.

We assume that at LF the quantified DP "every man$_i$" is raised and, moreover, the quantifier "every" is adjoined to IP and bears the same index as the DP out of which it is moved. The resulting LF for (18) is given in (19):

(19) Every$_i$ [man$_i$] [t$_i$ is such that he$_i$ runs]

[1] The notion of presupposition assumed here goes back to Strawson (1950). For a discussion of different notions of presupposition, see Soames (1989).

Assuming that the index on the quantifier and the noun translates as the plain variable "$x_i$", the translation of (19) is (20):

(20) $every\ x_i\ man(x_i)\ run(x_i^m)$

According to the semantic clause for quantified formulae in (14),

(21) a. $[\![every\ x_i\ man(x_i)\ run(x_i^m)]\!]_{M,c,c_g,c_w,c_t}$ is defined
only if $[\![run(x_i^m)]\!]_{M,c,g',c_w,c_t}$ is defined for every $g'$ such that $g'[x_i]c_g$ and $[\![man(x_i)]\!]_{M,c,g',c_w,c_t} = 1$
only if $g'(x_i)$ is human and male at $c_w, c_t$ for every $g'$ such that $g'[x_i]c_g$ and $[\![man(x_i)]\!]_{M,c,g',c_w,c_t} = 1$
only if every individual who is a man at $c_w, c_t$ is human and male at $c_w, c_t$.

b. if $[\![every\ x_i\ man(x_i)\ run(x_i^m)]\!]_{M,c,c_g,c_w,c_t}$ is defined, then:
"$every\ x_i\ man(x_i)\ run(x_i^m)$" is true in $c$ in $M$,
if $[\![every\ x_i\ man(x_i)\ run(x_i^m)]\!]_{M,c,c_g,c_w,c_t}$=1
if $[\![run(x_i^m)]\!]_{M,c,g',c_w,c_t} = 1$ for every $g'$ such that $g'[x_i]c_g$ and $[\![man(x_i)]\!]_{M,c,g',c_w,c_t} = 1$
if every individual who is a man at $c_w, c_t$ is male and human at $c_w, c_t$, and runs at $c_w, c_t$.

Notice that the presupposition of the pronoun "he", indicated by definedness condition (21-a), is trivially satisfied here, since every assignment $g'$ that satisfies the restrictor "$man(x_i)$" at the world and time of the context is such that the individual that $g'$ assigns to $x_i$ is male and human at the world and time of the context, thus $g'$ satisfies the presupposition of the nuclear scope "$run(x_i^m)$" as well.

## 6 Interaction with modal operators

The interaction of free third person pronouns with modal operators follows the general pattern pointed out by Kaplan for demonstratives. One general feature of demonstratives, according to Kaplan, is this:

(22) the descriptive content of demonstratives holds of their referent in the context in which they are uttered.

For example, an utterance of (23) below is true just in case the man the speaker is pointing at when uttering (23) is such that he might have been a communist. One cannot utter (23) to say of an individual that there is a possible circumstance in which that individual is a man and a communist.

(23) That man could have been a communist.

The same seems to be true of the descriptive content of third person pronouns. One cannot utter (24) below to say of an individual that there is a possible circumstance in which that individual is a human male and a communist. The descriptive content of the third person pronoun “he” must hold of its referent in the context in which (24) is uttered.

(24) He could have been a communist.

This behavior of the third person pronoun in (24) is predicted by the account we sketched. This depends on the fact that modal operators, as in Kaplan's system, may be assumed to shift the world of the circumstance of evaluation, while the descriptive content of (the presuppositional variable translating) the pronoun is required (by clauses (10)-(12)) to hold of the pronoun's referent in the world and time of the context. Let's see how this works in detail.

The semantic clause for the possibility operator is specified in this way:[2]

[2]According to the definedness condition in (25-a), the possibility operator “$\Diamond$” is a *plug* in Karttunen's (1974) sense, namely it blocks the presuppositions of the sentence in its scope. This is in contrast with Karttunen's observation that modals are *holes*, namely they turn the presuppositions of the sentence in their scope into presuppositions of the matrix sentence. For example, sentence (i) below inherits the presupposition that John talked before reaching maturity from the embedded sentence:

(i) it is possible that John stopped talking upon reaching maturity.

Notice, however, that, although modals expressing epistemic possibility usually behave as holes, modals expressing other types of possibility may not be holes (indeed, Soames 1989 restricts the assumption that modals are holes to epistemic modals). For example, (ii) does not require that in the world of the context every unicorn talks before reaching maturity:

(ii) It is possible that every unicorn stops talking upon reaching maturity.

The possibility operator in (ii) seems to be an operator of “informational” possibility, which is understood relative to what Kratzer (1981) calls an “informational conversational background”, namely a background that “represents the intentional content of sources of information” (where sources of information may be stories, books, reports, testimony etc.). One may adopt the definedness condition in (25-a) as a first approximation for this sense of “possible”.

(25) a. $[\![\Diamond\varphi]\!]_{M,c,g,w,t}$ is defined only if $[\![\varphi]\!]_{M,c,g,w',t}$ is defined for all $w' \in \mathcal{W}$ that are accessible[3] from $w$.

b. if $[\![\Diamond\varphi]\!]_{M,c,g,w,t}$ is defined, then:
$[\![\Diamond\varphi]\!]_{M,c,g,w,t} = 1$ if $[\![\varphi]\!]_{M,c,g,w',t} = 1$, for some $w' \in \mathcal{W}$ that is accessible from $w$;
$[\![\Diamond\varphi]\!]_{M,c,g,w,t} = 0$ if $[\![\varphi]\!]_{M,c,g,w',t} = 0$, for all $w' \in \mathcal{W}$ that are accessible from $w$.

Assuming that the LF for (24) is translated as (26), we get the desired truth-conditions in (27) by which the referent of the pronoun is required to be human and male at the world and time of the context:

(26) $\Diamond communist(x_i^m)$

(27) a. $[\![\Diamond communist(x_i^m)]\!]_{M,c,c_g,c_w,c_t}$ is defined
only if $[\![x_i^m]\!]_{M,c,c_g,w',c_t}$ is defined for all $w' \in \mathcal{W}$ that are accessible from $c_w$
only if $c_g(x_i)$ is human and male in $c_w$,$c_t$.

b. if $[\![\Diamond communist(x_i^m)]\!]_{M,c,c_g,c_w,c_t}$ is defined,then:
"$\Diamond communist(x_i^m)$" is true in a context $c$ in the model $M$
if $[\![\Diamond communist(x_i^m)]\!]_{M,c,c_g,c_w,c_t} = 1$
if $[\![communist(x_i^m)]\!]_{M,c,c_g,w',c_t} = 1$ for some $w' \in \mathcal{W}$ that is accessible from $c_w$
if $c_g(x_i)$ is human and male in $c_w$,$c_t$ and is a communist in $w'$, $c_t$ for some $w' \in \mathcal{W}$ that is accessible from $c_w$.

Free third person pronouns, and more generally demonstratives, share (22) with pure indexicals. For example, the first person pronoun "I" (a pure indexical) refers to the speaker of the context in which it is uttered. One cannot utter (28) to say of an individual that there is a possible circumstance where that individual is the speaker and is a communist:

(28) I might be a communist.

In Kaplan's theory, this is accounted for by assuming that pure indexicals directly refer to some features of the context of utterance. For example, the semantic clause for "I" is the following:

[3]We assume that the context of utterance specifies an accessibility relation which determines the modal base for the modal operator, along the lines of Kratzer (1977, 1978, 1981). We introduce the accessibility relation as a contextual coordinate in the final version of the formal system in Appendix 1.

(29) $[\![I]\!]_{M,c,g,w,t} = c_a$.

If we combine (29) with the account we are exploring here, however, the denotations of demonstratives and pure indexicals are anchored to the context of utterance by different means, and feature (22) is also accounted for differently. In our theory, demonstratives, in particular free third person pronouns, are variables whose referent is determined by a contextual assignment in virtue of the definition of truth in a context, which identifies the assignment of the circumstance with that of the context. Moreover, their descriptive content is presupposed to hold of their referent in the context of utterance. On the other hand, according to (29), pure indexicals like "I" are not variables, but constants which, in every context $c$, refer to some coordinate of $c$, for example "I" refers to the agent of $c$.

One might argue that this difference between pure indexicals like "I" and third person pronouns is legitimated by the observation that third person pronouns, unlike pure indexicals, may be bound by quantifiers, and, in this sense, they display a variable-like behavior that pure indexicals fail to display. Indeed, "I" in (30) cannot be bound by the quantified NP "every man":

(30) every man thinks I am a communist.

However, lack of quantifier binding for pure indexicals might also be explained by syntactic means. Presumably, when pronouns are bound, the Phi features (gender, number, and person) of the binder and of the bindee must agree,[4] and this is sufficient to rule out the binding in (30), since "every man" is third person and "I" is first person. If this is the case, then one possibility is that "I" is translated as a variable as well and its semantics is specified thus (see also Santorio 2012 for a proposal that treats "I" as a variable):

(31) I $\Rightarrow x_i^s$.

(32) $[\![x_i^s]\!]_{M,c,g,w,t} = g(x_i)$ if $g(x_i) = c_a$, and it's undefined otherwise.

Here, we leave it open whether first person pronouns should be treated as constants, as in (29), or as variables, as in (31)-(32).[5]

[4]For this assumption, see Kratzer (1998, 2009) and Heim (2008).

[5]See Sudo (2012, 2013a) for further discussion.

## 7 The fundamental problem

The semantics for third person pronouns proposed in section 5 is in essence the account of free third person pronouns proposed by Cooper (1983). According to Cooper, these pronouns have *indexical presuppositions*, namely they presuppose that their descriptive content is satisfied by their referent in the actual world.

Cooper restricts the indexical presuppositions to (non anaphoric) free third person pronouns and claims that bound pronouns do not trigger them. One consequence of the unified account proposed here, however, is that we expect them to be met by bound third person pronouns as well. Yanovich (2010) has provided some examples of bound pronouns interacting with attitude operators showing that their gender presuppositions may be indexical in Cooper's sense. However, as Yanovich observes, there are also cases in which an attitude operator or a conditional antecedent succeeds in blocking the requirement that the descriptive content be met in the actual world (see Sudo 2012 for discussion). The problem with the proposal sketched so far is that it predicts that the gender presuppositions of pronouns, whether bound or free, should always be satisfied by their referent in the world of the context.

We may see why this is a problem in the case of modal operators by considering (33):

(33) It is possible that every unicorn$_i$ is such that it$_i$ talks.

Clearly, in the case of (33), the gender presuppositions of the pronoun "it$_i$", do not have to be satisfied by any individual in the actual world. But our theory does not predict this. According to the proposal in section 5,

(34) a. $[\![\Diamond\ every\ x_i\ unicorn(x_i)\ talk(x_i^n)]\!]_{M,c,c_g,c_w,c_t}$ is defined
only if, for all $w$ that are accessible from $c_w$,
$[\![every\ x_i\ unicorn(x_i)\ talk(x_i^n)]\!]_{M,c,c_g,w,c_t}$ is defined
only if, for all $w$ that are accessible from $c_w$, $[\![talk(x_i^n)]\!]_{M,c,g',w,c_t}$
is defined for every $g'$ such that $g'[x_i]c_g$ and
$[\![unicorn(x_i)]\!]_{M,c,g',w,c_t} = 1$
only if, for all $w$ that are accessible from $c_w$, every individual which is a unicorn at $w$, $c_t$ is non human at $c_w$, $c_t$.

b. If $[\![\Diamond\ every\ x_i\ unicorn(x_i)\ talk(x_i^n)]\!]_{M,c,c_g,c_w,c_t}$ is defined, then:
"$\Diamond\ every\ x_i\ unicorn(x_i)\ talk(x_i^n)$" is true in $c$ in $M$,
if $[\![\Diamond\ every\ x_i\ unicorn(x_i)\ talk(x_i^n)]\!]_{M,c,c_g,c_w,c_t} = 1$

if $[\![every\ x_i\ unicorn(x_i)\ talk(x_i^n)]\!]_{M,c,c_g,w,c_t} = 1$ for some $w$ that is accessible from $c_w$,
if for some $w$ that is accessible from $c_w$, $[\![talk(x_i^n)]\!]_{M,c,g',w,c_t} = 1$ for every $g'$ such that $g'[x_i]c_g$ and $[\![unicorn(x_i)]\!]_{M,g',w,c_t} = 1$
if, for some $w$ that is accessible from $c_w$, every individual that is a unicorn at $w, c_t$ is non human at $c_w, c_t$, and talks at $w, c_t$.

This prediction is incorrect since it requires that, for (33) to be true non vacuously, there must be some non human individuals in the actual world such that there is some world in which they are unicorns and talk.

Two observations are in order concerning this problem. The first is that we cannot solve it simply by modifying the semantics of third person pronouns and requiring that their descriptive content be met at the world and time *of the circumstance*. This is a natural way to extend Kratzer and Heim's treatment of the presuppositions of third person pronouns to an intensional semantics (see Sudo 2012 for an explicit formulation), and in our system it would amount to assuming the following interpretation for the presuppositional variables translating third person pronouns:

(35) $[\![x_i^m]\!]_{M,c,g,w,t} = g(x_i)$ if $g(x_i)$ is human and male in $w$ at $t$, and it's undefined otherwise.

(36) $\left[\!\left[x_i^f\right]\!\right]_{M,c,g,w,t} = g(x_i)$ if $g(x_i)$ is human and female in $w$ at $t$, and it's undefined otherwise.

(37) $[\![x_i^n]\!]_{M,c,g,w,t} = g(x_i)$ if $g(x_i)$ is not human in $w$ at $t$, and it's undefined otherwise.

However, this interpretation predicts that one should be able to point at Fabio and utter (38) below to claim that there is some possible circumstance in which he is a woman. The problem is that (38) is not felicitous in a context of this kind.

(38) she$_i$ might have been a woman.

The second observation is that the problem posed by (33) is not generated by our assumption that the variable assignment is both a coordinate of the context and a coordinate of the circumstance of evaluation. Indeed, consider the monstrous counterpart of (14):

(39) a. $[\![every\ \nu\ \Phi\Psi]\!]_{M,c,w,t}$ is defined only if $[\![\Psi]\!]_{M,c',w,t}$ is defined for every $c'$ that differs from $c$ at most because $[\![\nu]\!]_{M,c',w,t} \neq [\![\nu]\!]_{M,c,w,t}$ and such that $[\![\Phi]\!]_{M,c',w,t} = 1$.

b. if $[\![every\ \nu\ \Phi\Psi]\!]_{M,c,w,t}$ is defined, then:
$[\![every\ \nu\ \Phi\Psi]\!]_{M,c,w,t} = 1$ if $[\![\Psi]\!]_{M,c',w,t} = 1$ for every $c'$ that differs from $c$ at most because $[\![\nu]\!]_{M,c',w,t} \neq [\![\nu]\!]_{M,c,w,t}$ and such that $[\![\Phi]\!]_{M,c',w,t} = 1$; otherwise $[\![every\ \nu\ \Phi\Psi]\!]_{M,c,w,t} = 0$.

If the assignment is only present as a contextual coordinate, as the monstrous treatment of quantifiers would have it, we still have the option, when specifying the interpretation of third person pronouns, of requiring that their descriptive content be met at the time and world of the context or at the time and world of the circumstance. In the first case, the monstrous theory makes the same wrong prediction about (33) as the proposal in section 5, in the second case it makes the same wrong prediction as (36) concerning (38). In other words, what generates the problem here is the attempt to provide a *uniform semantics* for third person pronouns whether bound or free, not the choice of a non monstrous account of quantifiers over a monstrous one.

This is then the fundamental problem that arises for any account that treats bound and (non anaphoric) free uses of third person pronouns as occurrences of the same lexical items. On the one hand, (non anaphoric) free uses provide compelling reasons to assume that the descriptive content of the pronoun should be met in the world of the context. On the other hand, bound uses show that this need not be the case.

# 8 Looking for a solution

The theory we propose in this section is our attempt to solve the fundamental problem. We sketch our proposal in two steps: first we present a simple version of the theory to convey the intuitive idea underlying it, then we introduce some changes to improve its empirical coverage.

## 8.1 Modal localization of the assignment

Consider (40):

(40) Every student$_i$ is such that he$_i$ passed the exam.

Intuitively, when we utter (40), we are considering individuals that inhabit the world of the context of utterance and are students in that world. If the compositional interpretation of (40) is achieved by quantifying over alternative assignments, the truth-conditions for (40) may be spelled out thus: every alternative assignment that assigns to the variable bound by the quantifier an individual that inhabits the world of the context $c_w$ and is a student in $c_w$ must also be an assignment that makes the translation of "he$_i$ passed the exam" true in $c_w$.

Now consider (33) again:

(33) It is possible that every unicorn$_i$ is such that it$_i$ talks.

Intuitively, when we utter (33), we are not considering individuals that inhabit the world of the context of utterance and are unicorns in that world. We consider, instead, individuals that inhabit a possible world which may differ from the world of the context and that are unicorns in that world. If the compositional interpretation of (33) is achieved by quantifying over alternative assignments, the truth-conditions for (33) may be spelled out thus: there must be some world $w$ such that every alternative assignment that assigns to the variable bound by the quantifier an individual that inhabits $w$ and is a unicorn in $w$ is also an assignment that makes the translation of "it$_i$ talks" true in $w$.

One moral we may draw from this picture is that assignments are modally localized: by this, we mean that an assignment doesn't just assign individuals to variables, but also carries information about which world is inhabited by these individuals. We formalize this idea by assuming that variable assignments are parameterized to possible worlds, and we write $g^w$ for an assignment parameterized to the possible world $w$. We assume the following *principle of localization*:

(41) for every $\nu \in \mathcal{V}$, $g^w(\nu)$ is an individual *inhabiting* $w$.

We keep to our previous assumption that the assignment is initialized by the context, i.e. at the beginning of the evaluation process the assignment of the circumstance is the same as the contextual assignment. However, since assignments are now parameterized to a possible world, we need to say how the world parameter of the contextual assignment is set up. We make the natural assumption that the contextual assignment is parameterized to the world of the context, that is, the assignment of context $c$ is $c_g^{c_w}$. Truth in a context is now defined thus:

- $\Phi$ is true in a context $c$, in the model $M$, if $[\![\Phi]\!]_{M,c,c_g^{c_w},c_w,c_t} = 1$
- $\Phi$ is false in a context $c$, in the model $M$, if $[\![\Phi]\!]_{M,c,c_g^{c_w},c_w,c_t} = 0$

### 8.2 Assignment shifts

Now that assignments are parameterized to possible worlds, we need to be more explicit on the possible ways the assignment coordinate of the circumstance can be shifted. As before, the assignment will be operated upon by quantifiers (and the $\lambda$-operator), the only assignment-shifters in our system. We will now state the semantic clauses for quantified DPs and modal operators by following these assumptions:

- a quantifier binding a variable $\nu$ introduces variants of the input assignment that (i) may differ from it with respect to the value of $\nu$ and (ii) are parameterized to the world of the circumstance of evaluation $w$;

- modal operators only shift the *world*-coordinate of the circumstance of evaluation, while they do nothing to the *assignment*-coordinate of the circumstance.

Constraint (ii) on the output assignments of quantifiers is supposed to account for the observation that a quantified DP in the scope of a modal operator has a domain which is restricted to individuals inhabiting the world introduced by the modal operator.

In stating the semantic clause for the universal quantifier based on these assumptions, some care is needed. In principle, the input assignment for a quantifier need not be parameterized to the world of the context, since, by (ii) above, another quantifier might have parameterized it to the world of the circumstance of evaluation. For example, in (42) below, the quantifier "every female unicorn", if interpreted in the scope of the quantifier "every male unicorn", takes an input assignment parameterized to the world of the circumstance:

(42) It is possible that every male unicorn loves every female unicorn.

However, the input assignment for a quantifier need not be parameterized to the world of the circumstance either, since a modal operator might have shifted the world of the circumstance, while the input assignment might have remained anchored to the world of the context. This is the case for the quantifier "every male unicorn" in (42), if understood as taking scope over "every female unicorn".

We take these options into account, by specifying the clause for universally quantified formulae as in (43) (where @ is a world and the expression "$g'^{w}[\nu]g^{@}$" is short for "$g'^{w}$ is the assignment identical to $g^{@}$ except for the fact that (i) the world parameter of $g'^w$ is $w$ and (ii) the individual $g'^w(\nu)$ may differ from the individual $g^@(\nu)$"):

(43) a. $[\![every\ \nu\ \Phi\Psi]\!]_{M,c,g^@,w,t}$ is defined only if $[\![\Psi]\!]_{M,c,g'^w,w,t}$ is defined for every $g'^w$ such that $g'^w[\nu]g^@$ and $[\![\Phi]\!]_{M,c,g'^w,w,t} = 1$.

b. if $[\![every\ \nu\ \Phi\Psi]\!]_{M,c,g^@,w,t}$ is defined, $[\![every\ \nu\ \Phi\Psi]\!]_{M,c,g^@,w,t} = 1$ if $[\![\Psi]\!]_{M,c,g'^w,w,t} = 1$ for every $g'^w$ such that $g'^w[\nu]g^@$ and $[\![\Phi]\!]_{M,c,g'^w,w,t} = 1$; otherwise $[\![every\ \nu\ \Phi\Psi]\!]_{M,c,g^@,w,t} = 0$.

The clause for the possibility operator will be essentially the same as the one we gave in section 6, the only difference being that the assignment coordinate is now modally parameterized:

(44) a. $[\![\Diamond\varphi]\!]_{M,c,g^@,w,t}$ is defined only if $[\![\varphi]\!]_{M,c,g^@,w',t}$ is defined for all $w' \in \mathcal{W}$ that are accessible from $w$.

b. if $[\![\Diamond\varphi]\!]_{M,c,g^@,w,t}$ is defined, then:
$[\![\Diamond\varphi]\!]_{M,c,g^@,w,t} = 1$ if $[\![\varphi]\!]_{M,c,g^@,w',t} = 1$, for some $w' \in \mathcal{W}$ that is accessible from $w$;
$[\![\Diamond\varphi]\!]_{M,c,g^@,w,t} = 0$ if $[\![\varphi]\!]_{M,c,g^@,w',t} = 0$, for all $w' \in \mathcal{W}$ that are accessible from $w$.

### 8.3 Adherence of the presupposition to the world of the assignment

Another essential ingredient of the solution that we propose is what we call "adherence of the presupposition to the world of the assignment", by which we mean (45):

(45) If the reference of a pronoun $pro_n$ is determined by assignment $g^w$, the presupposition triggered by $pro_n$ must be met in $w$, that is, the individual $g^w(x_n)$ must satisfy the relevant presupposition in $w$.

Formally, principle (45) is captured by the following reformulation of the clauses for the denotation of the presuppositional variables translating third person pronouns:

(46) $[\![x_i^m]\!]_{M,c,g^@,w,t} = g^@(x_i)$ if $g^@(x_i)$ is human and male in @, and it's undefined otherwise.

(47) $\left[\!\!\left[x_i^f\right]\!\!\right]_{M,c,g^@,w,t} = g^@(x_i)$ if $g^@(x_i)$ is human and female in @, and it's undefined otherwise.

(48) $[\![x_i^n]\!]_{M,c,g^@,w,t} = g^@(x_i)$ if $g^@(x_i)$ is non human in @, and it's undefined otherwise.

## 8.4 Indexical vs. shifty behaviour of pronominal presuppositions

It's easy to show that the revised system based on modally parameterized assignments can still account for the indexical behaviour of pronominal presuppositions described by Cooper (1983), while enabling one to face the empirical challenge raised by quantifiers in modal contexts which was discussed in section 7.

Let's begin with the case of the indexical presupposition in the scope of a modal operator corresponding to our example (24), whose LF we have assumed to be translated as in (26):

(24) He$_i$ could have been a communist.

(26) $\Diamond communist(x_i^m)$

We now predict the following truth conditions for an utterance of (24) in a context $c$, by which the referent of the pronoun is correctly required to be human and male in the world of $c$:

(49) a. $[\![\Diamond communist(x_i^m)]\!]_{M,c,c_g^{c_w},c_w,c_t}$ is defined only if $[\![communist(x_i^m)]\!]_{M,c,c_g^{c_w},w',c_t}$ is defined for all accessible $w' \in \mathcal{W}$ only if $[\![x_i^m]\!]_{M,c,c_g^{c_w},w',c_t}$ is defined for all accessible $w' \in \mathcal{W}$ only if $c_g^{c_w}(x_i)$ is human and male in $c_w$,$c_t$.

b. If $[\![\Diamond communist(x_i^m)]\!]_{M,c,c_g^{c_w},c_w,c_t}$ is defined, then:
"$\Diamond communist(x_i^m)$" is true in $c$ in the model $M$
if $[\![\Diamond communist(x_i^m)]\!]_{M,c,c_g^{c_w},c_w,c_t} = 1$
if $[\![communist(x_i^m)]\!]_{M,c,c_g^{c_w},w',c_t} = 1$ for some accessible $w' \in \mathcal{W}$
if $[\![x_i^m]\!]_{M,c,c_g^{c_w},w',c_t} \in [\![communist]\!]_{M,c,c_g^{c_w},w',c_t}$ for some accessible $w' \in \mathcal{W}$
if $c_g^{c_w}(x_i)$ is human and male in $c_w$,$c_t$ and is communist in $w'$, $c_t$ for some accessible $w' \in \mathcal{W}$.

Let's now turn to the shifty case provided by quantifiers in the semantic scope of modal operators, as shown by the example (33):

(33) It is possible that every unicorn$_i$ is such that it$_i$ talks.

According to the present proposal,

(50) a. $[\![\Diamond\ every\ x_i\ unicorn(x_i)\ talk(x_i^n)]\!]_{M,c,c_g^{c_w},c_w,c_t}$ is defined only if, for all accessible $w$, $[\![talk(x_i^n)]\!]_{M,c,g^w,w,c_t}$ is defined for every $g^w$ such that $g^w[x_i]c_g^{c_w}$ and $[\![unicorn(x_i)]\!]_{M,c,g^w,w,c_t} = 1$
only if, for all accessible $w$, every individual which is a unicorn at $w$, $c_t$ is non human at $w$, $c_t$.

b. if $[\![\Diamond\ every\ x_i\ unicorn(x_i)\ talk(x_i^n)]\!]_{M,c,c_g^{c_w},c_w,c_t}$ is defined, then: "$\Diamond\ every\ x_i\ unicorn(x_i)\ talk(x_i^n)$" is true in $c$, in the model $M$, if $[\![\Diamond\ every\ x_i\ unicorn(x_i)\ talk(x_i^n)]\!]_{M,c,c_g^{c_w},c_w,c_t} = 1$
if $[\![every\ x_i\ unicorn(x_i)\ talk(x_i^n)]\!]_{M,c,c_g^{c_w},w,c_t} = 1$ for some accessible $w$
if, for some accessible $w$, $[\![talk(x_i^n)]\!]_{M,c,g^w,w,c_t} = 1$ for every $g^w$ such that $g^w[x_i]c_g^{c_w}$ and $[\![unicorn(x_i)]\!]_{M,c,g^w,w,c_t} = 1$
if, for some accessible $w$, every individual that is a unicorn at $w, c_t$ is non human at $w, c_t$, and talks at $w, c_t$.

Thus, the new proposal correctly captures the modally bound presupposition of (33), according to which unicorns are only presupposed to be non human in the possible world introduced by the possibility operator, not in the world of the context.

## 8.5 Modal localization of the assignment again

We are not done yet. We made the following assumptions to account for the fact that the presuppositions of bound pronouns need not be satisfied at the world of the context: (i) variable assignments are parameterized to a world, and (ii) the denotations of the presuppositional variables "$x_i^m$", "$x_i^f$", "$x_i^n$" translating third person pronouns are only defined if the values of the corresponding plain variables are, respectively, male, female, neither male nor female at that world. Since quantifiers identify the world parameter of the assignment with the world of the circumstance of evaluation, the denotation of presuppositional variables need not be defined relative to the world of the context when these variables are in the scope of quantifiers. As we saw, this is a desired consequence in the case of (33) above. However, the proposal we just sketched needs to be improved. Here's why.

Let's assume that intensional operators like "according to x", on a par with modal operators, shift the world coordinate of the circumstance, but not the world of the assignment. Now, suppose that, while we know that Fabio is male, Jones falsely believes that Fabio is female. Our current proposal correctly predicts that sentence (51) below cannot be uttered felicitously in this context to report that, according to Jones, Fabio works in

Toulouse:

(51) According to Jones, she (pointing at Fabio) works in Toulouse.

The proposal makes this prediction, since it requires that the presupposition of the pronoun "she" in (51) be met at the world of the assignment, which, in this case, is the world of the context.[6] Consider, however, sentence (52):

(52) According to Jones, every student loves her (pointing at Fabio).

Again, this sentence cannot be uttered felicitously against the background we considered, in which Jones wrongly believes that Fabio is female. Yet, our current proposal incorrectly predicts that (52) should be felicitous if uttered against that background. In short, the reason is this. In (52), the quantifier "every student" is in the scope of the intensional operator "according to Jones", thus the alternative assignments introduced by the quantifier are parameterized to the worlds introduced by the intensional operator, namely to Jones's epistemic alternatives. For this reason, the pronoun "her" ends up being evaluated relative to assignments parameterized to Jones's epistemic alternatives. As a consequence, the presupposition of "her" is satisfied, since, in the context at hand, Jones believes that Fabio is female, thus (52) is incorrectly predicted to be felicitous in that context. To see how the problem arises in detail, let's assume that "according to Jones" is translated in IL by the operator $B_j$ with the following semantics:

(53) a. $[\![B_j\varphi]\!]_{M,c,g^{@},w,t}$ is defined only if $[\![\varphi]\!]_{M,c,g^{@},w',t}$ is defined for every $w' \in \mathcal{W}$ which is a belief world of Jones in $w$.

b. If $[\![B_j\varphi]\!]_{M,c,g^{@},w,t}$ is defined, then:
$[\![B_j\varphi]\!]_{M,c,g^{@},w,t} = 1$ if $[\![\varphi]\!]_{M,c,g^{@},w',t} = 1$, for every $w' \in \mathcal{W}$ which is a belief world of Jones in $w$;
$[\![B_j\varphi]\!]_{M,c,g^{@},w,t} = 0$ if $[\![\varphi]\!]_{M,c,g^{@},w',t} = 0$, for some $w' \in \mathcal{W}$ which is is a belief world of Jones in $w$.

Sentence (52) is now translated as (54):

(54) $B_j$ $every\ x_i\ student(x_i)\ loves(x_k^f, x_i)$

[6] Here, we are implicitly assuming that, if a proposition $p$ must be true in the world of the context in order for a sentence S to have a truth value, then in order for S to be felicitously utterable in that context, the conversational participants must take for granted that $p$. We make this assumption explicit in section 9.2 by stating the bridge principle in (94).

According to our current proposal, (54) is defined under the following conditions:

(55) $\left[\!\left[B_j\ every\ x_i\ student(x_i)\ loves(x_k^f, x_i)\right]\!\right]_{M,c,c_g^{c_w},c_w,c_t}$ is defined
only if $\left[\!\left[every\ x_i\ student(x_i)\ loves(x_k^f, x_i)\right]\!\right]_{M,c,c_g^{c_w},w',c_t}$ is defined, for every $w' \in \mathcal{W}$ which is a belief world of Jones in $c_w$
only if $\left[\!\left[loves(x_k^f, x_i)\right]\!\right]_{M,c,g^{w'},w',c_t}$ is defined for every $g^{w'}$ such that $g^{w'}[x_i]c_g^{c_w}$ and $[\![student(x_i)]\!]_{M,c,g^{w'},w',c_t} = 1$ , for every $w' \in \mathcal{W}$ which is a belief world of Jones in $c_w$
only if $\left[\!\left[x_k^f\right]\!\right]_{M,c,g^{w'},w',c_t}$ is defined for every $w' \in \mathcal{W}$ which is a belief world of Jones in $c_w$
only if $g^{w'}(x_k)$ is female in $w'$ for every $w' \in \mathcal{W}$ which is a belief world of Jones in $c_w$.

Thus, we predict that the presupposition of the female pronoun "her" in (52) must be met in Jones's belief worlds, contrary to what is the case.[7]

As (55) shows, the problem originates from the fact that our system, as it is, requires that the presuppositions of pronouns in the scope of quantifiers must be met at the world of the circumstance not only when these pronouns are bound, as in (33), but also when they are free, as in (52). Thus, in configurations of type (56) below, where the pronoun is free and is in the scope of a quantifier, we predict that the presupposition of the pronoun must be met at the worlds introduced by the intensional operator:

[7]There is a further problem with the formulation of the semantic clause for universal quantifiers we proposed in (43), as pointed out to us by Philippe Schlenker (p.c.). By our principle of localization in (41), given an assignment $g^{@}$, there may be no such thing as the assignment $g'^{w}$ which, besides possibly differing from $g^{@}$ for the world parameter, agrees with $g^{@}$ on the values assigned to all variables except possibly for the value of a variable $\nu$:

(41) *Principle of localization*: for every $\nu \in \mathcal{V}$, $g^{w}(\nu)$ is an individual *inhabiting* $w$.

Indeed, suppose that $a$ inhabits @, but not $w$, and, moreover, $g^{@}$ assigns $a$ to a variable $\nu'$ different from $\nu$. Then, given that, by (41), any assignment $g'^{w}$ that is a variant of $g^{@}$ with respect to the value of $\nu$ must assign to $\nu'$ an individual inhabiting $w$, no such assignment $g'^{w}$ may differ from $g^{@}$ *only* for the value it assigns to $\nu$. The unwanted consequence of this is that (i) below may turn out to be vacuously true because there is some world inhabited by unicorns but not by an individual assigned by the context to the variable $x_j$:

(i) It is possible that every unicorn$_i$ is such that it$_i$ is not a unicorn.

(56) Intensional operator [quantifier ... free pronoun ...]

But (52) shows that this prediction is not correct. In order to avoid this incorrect prediction, the formal system must be revised in such a way that only the denotations of *bound* presuppositional variables are required to be defined relative to the world of the circumstance of evaluation. This is what we set out to do now.

First, we assume that assignments are not directly parameterized to a world, but to a function $s$ from plain variables to worlds:

(57) $g^s$

Thus, an assignment, besides assigning an individual to each plain variable, also contains "modal" information concerning which world is associated with which variable. For short, let's call the function $s$ from plain variables to worlds the "modal component" of the assignment function. We assume that the assignment provided by the context is specified thus:

(58) $c_g^s$, where $s(\nu) = c_w$ for every $\nu \in \mathcal{V}$.

Namely, the modal component of the contextual assignment associates each variable with the actual world. The *principle of localization* is now restated as follows:

(59) For every $\nu \in \mathcal{V}$ and every function $s$ from $\mathcal{V}$ to $\mathcal{W}$, $g^s(\nu)$ is an individual *inhabiting* $s(\nu)$.

This means that, as before, the contextual assignment assigns to each plain variable an individual inhabiting the world of the context, but this is now obtained by parameterizing the assignment to a function from variables to worlds, rather than to a world directly.

The denotation of presuppositional variables is now restated thus:

(60) $[\![x_i^m]\!]_{M,c,g^s,w,t} = g^s(x_i)$ if $g^s(x_i)$ is human and male in $s(x_i)$, and it's undefined otherwise.

(61) $\left[\left[x_i^f\right]\right]_{M,c,g^s,w,t} = g^s(x_i)$ if $g^s(x_i)$ is human and female in $s(x_i)$, and it's undefined otherwise.

(62) $[\![x_i^n]\!]_{M,c,g^s,w,t} = g^s(x_i)$ if $g^s(x_i)$ is non human in $s(x_i)$, and it's undefined otherwise.

The clauses for the possibility operator "$\Diamond$" and the operator "$B_j$" translating "according to Jones" stay the same, except for the fact that denotation is now relative to an assignment $g^s$ parameterized to a function $s$ from plain variables to worlds.

Let the expression "$g'^{s[\nu_i \to w, \dots, \nu_j \to w']}[\nu_i, \dots, \nu_j]g^s$" be short for "the assignment $g'^{s[\nu_i \to w, \dots, \nu_j \to w']}$ is identical to $g^s$ except for the fact that (i) $g'^{s[\nu_i \to w, \dots, \nu_j \to w']}$ may differ from $g^s$ because its modal component assigns the world $w$ to the variable $\nu_i$, ... , and the world $w'$ to the variable $\nu_j$, and (ii) $g'^{s[\nu_i \to w, \dots, \nu_j \to w']}$ may differ from $g^s$ for the individuals assigned to $\nu_i, \dots, \nu_j$". We may now restate the clause for the quantifier "*every*" as follows:

(63) a. $[\![every\ \nu\ \Phi\Psi]\!]_{M,c,g^s,w,t}$ is defined only if $[\![\Psi]\!]_{M,c,g'^{s[\nu \to w]},w,t}$ is defined for every $g'^{s[\nu \to w]}$ such that $g'^{s[\nu \to w]}[\nu]g^s$ and $[\![\Phi]\!]_{M,c,g'^{s[\nu \to w]},w,t} = 1$.

b. if $[\![every\ \nu\ \Phi\Psi]\!]_{M,c,g^s,w,t}$ is defined, then: $[\![every\ \nu\ \Phi\Psi]\!]_{M,c,g^s,w,t} = 1$ if $[\![\Psi]\!]_{M,c,g'^{s[\nu \to w]},w,t} = 1$ for every $g'^{s[\nu \to w]}$ such that $g'^{s[\nu \to w]}[\nu]g^s$ and $[\![\Phi]\!]_{M,c,g'^{s[\nu \to w]},w,t} = 1$; otherwise $[\![every\,\nu\ \Phi\Psi]\!]_{M,c,g^s,w,t} = 0$.

One consequence of (63) is that the quantifier now introduces variants of the input assignment where only the values of variables bound by the quantifier are localized at the world of the circumstance. This yields the desired result that only the denotations of *bound* presuppositional variables are required to be defined relative to the world of the circumstance of evaluation.[8] Indeed, in the case of (52), repeated below with its IL translation in (54), the presupposition of "her" must now be satisfied relative to the world of the context and not in Jones's belief worlds:

(52) According to Jones, every student loves her (pointing at Fabio).

(54) $B_j\ (every\ x_i\ student(x_i)\ loves(x_k^f, x_i))$

(64) $\left[\!\left[B_j\ (every\ x_i\ student(x_i)\ loves(x_k^f, x_i))\right]\!\right]_{M,c,c_g^s,c_w,c_t}$ is defined

[8] Notice that the problem pointed out for the previous version of our proposal in relation to (i) no longer arises:

(i) It is possible that every unicorn$_i$ is such that it$_i$ is not a unicorn.

What is required now for (i) to be true in a context $c$ is that this condition be met: there is a world $w$ such that every assignment which assigns to the variable $x_i$ an individual inhabiting $w$ that is a unicorn in $w$, and which otherwise agrees with the assignment of the context on assigning to other variables individuals inhabiting $c_w$, also assigns to $x_i$ an individual that is not a unicorn in $w$. Clearly, no such condition may be satisfied.

only if $\left[\!\left[every\ x_i\ student(x_i)\ loves(x_k^f, x_i)\right]\!\right]_{M,c,c_g^s,w',c_t}$ is defined, for every $w' \in \mathcal{W}$ which is a belief world of Jones
only if $\left[\!\left[loves(x_k^f, x_i)\right]\!\right]_{M,c,g^{s[x_i \to w']},w',c_t}$ is defined for every $g^{s[x_i \to w']}$ such that $g^{s[x_i \to w']}[x_i]c_g^s$ and $[\![student(x_i)]\!]_{M,c,g^{s[x_i \to w']},w',c_t} = 1$, for every $w' \in \mathcal{W}$ which is a belief world of Jones
only if $\left[\!\left[x_k^f\right]\!\right]_{M,c,g^{s[x_i \to w']},w',c_t}$ is defined for every $w' \in \mathcal{W}$ which is a belief world of Jones
only if $g^{s[x_i \to w']}(x_k)$ is human and female in $s[x_i \to w'](x_k)$ for every $w' \in \mathcal{W}$ which is a belief world of Jones
only if $c_g^s(x_k)$ is female in $s(x_k) = c_w$.

According to the definedness condition which has thus been derived, (52) imposes a constraint on the context by which the denotation of "her" under the contextual assignment must be female in the world of the context.

# 9 Testing the theory further

## 9.1 Extension to other intensional operators

Our theory straightforwardly accounts for the behaviour of third person pronouns in (65) (based on Cooper 1983) and (66) (from Sudo 2012):

(65) Context: we know that Fabio is a man, but Jones believes that Fabio is a woman.

a. ??Jones believes that she$_i$ (pointing at Fabio) is a university professor.
b. ??Jones doubts that she$_i$ (pointing at Fabio) is a university professor.
c. ??Jones hopes that she$_i$ (pointing at Fabio) is a university professor.
d. ??Jones asked if she$_i$ (pointing at Fabio) is a university professor.
e. ??Jones wonders if she$_i$ (pointing at Fabio) is a university professor.

(66) Context: John met some new people today and said that some of them are students and some of them are professors. We do not know if he is right about that.

a. John believes that every student$_i$ likes herself$_i$.
b. John doubts that every student$_i$ likes herself$_i$.

c. John hopes that every student$_i$ likes herself$_i$.
d. John asked if every student$_i$ likes herself$_i$.
e. John wonders if every student$_i$ likes herself$_i$.

Assuming that the semantics of "believe" is similar to that of "according to", and is spelled out as in (67) below, the infelicity of (65-a) is explained on a par with the infelicity of (51): "she$_i$" is free in the LF of (65-a), thus the denotation of (the presuppositional variable translating) "she$_i$" is defined in a context only if the contextual assignment assigns to the plain variable $x_i$ an individual who is female in the world of the context. Since the contextual assignment assigns Fabio to $x_i$ and we know that Fabio is male, we correctly predict that (65-a) cannot be uttered felicitously in the context described in (65).

(67) a. $[\![believe(\tau,\varphi)]\!]_{M,c,g^s,w,t}$ is defined only if $[\![\varphi]\!]_{M,c,g^s,w',t}$ is defined, for all $w' \in \mathcal{W}$ such that $w'$ is a belief world of $[\![\tau]\!]_{M,c,g^s,w,t}$ in $w$.
b. if $[\![believe(\tau,\varphi)]\!]_{M,c,g^s,w,t}$ is defined, then:
$[\![believe(\tau,\varphi)]\!]_{M,c,g^s,w,t} = 1$ if $[\![\varphi]\!]_{M,c,g^s,w',t} = 1$, for all $w' \in \mathcal{W}$ such that $w'$ is a belief world of $[\![\tau]\!]_{M,c,g^s,w,t}$ in $w$;
$[\![believe(\tau,\varphi)]\!]_{M,c,g^s,w,t} = 0$ if $[\![\varphi]\!]_{M,c,g^s,w',t} = 0$, for some $w' \in \mathcal{W}$ such that $w'$ is a belief world of $[\![\tau]\!]_{M,c,g^s,w,t}$ in $w$.

An appropriate possible world semantics for "doubt", "hope", "ask", and "wonder" will account in the same way for (65-b)-(65-e), since, like "believe", these verbs do not introduce variants of the input assignment, thus the presupposition of "she", again, must be satisfied relative to the world of the context.

On the other hand, for (66-a) we predict (what is observed by Sudo) that the presupposition of "herself" must be satisfied in John's belief worlds, namely (66-a) is only felicitous in contexts in which John believes that every student is female. Here's why. As Sudo points out, the context in (66) indicates that the quantifier "every student$_i$" is to be read *de dicto*. Thus, (66-a) will be translated as (68):

(68) $believe(j, every\ x_i\ student(x_i)\ loves(x_i^f, x_i))$

Formula (68) is defined in a context under these conditions:

(69) $\left[\!\!\left[believe(j, every\ x_i\ student(x_i)\ loves(x_i^f, x_i))\right]\!\!\right]_{M,c,c_g^s,c_w,c_t}$ is defined

only if $\left[\!\left[ every\ x_i\ student(x_i)\ loves(x_i^f, x_i) \right]\!\right]_{M,c,c_g^s,w',c_t}$ is defined, for every $w' \in \mathcal{W}$ which is a belief world of Jones in $c_w$
only if $\left[\!\left[ loves(x_i^f, x_i) \right]\!\right]_{M,c,g^{s[x_i \to w']},w',c_t}$ is defined for every $g^{s[x_i \to w']}$ such that $g^{s[x_i \to w']}[x_i]c_g^s$ and $[\![student(x_i)]\!]_{M,c,g^{s[x_i \to w']},w',c_t} = 1$, for every $w' \in \mathcal{W}$ which is a belief world of Jones in $c_w$
only if $\left[\!\left[ x_i^f \right]\!\right]_{M,c,g^{s[x_i \to w']},w',c_t}$ is defined for every $g^{s[x_i \to w']}$ such that $g^{s[x_i \to w']}[x_i]c_g^s$ and $[\![student(x_i)]\!]_{M,c,g^{s[x_i \to w']},w',c_t} = 1$, for every $w' \in \mathcal{W}$ which is a belief world of Jones in $c_w$
only if for every $g^{s[x_i \to w']}$ such that $g^{s[x_i \to w']}[x_i]c_g^s$ and $[\![student(x_i)]\!]_{M,c,g^{s[x_i \to w']},w',c_t} = 1$, $g^{s[x_i \to w']}(x_i)$ is female in $s[x_i \to w'](x_i)$, for every $w' \in \mathcal{W}$ which is a belief world of Jones in $c_w$
only if every individual who is a student in $w'$ is female in $w'$, for every $w'$ which is a belief world of Jones in $c_w$.

The interpretation of (66-b)-(66-e) is accounted for in a similar way, under a suitable analysis of the intensional verbs occurring in these sentences.

Yet another case our theory accounts for is the following, based on Yanovich (2010):

(70) Context: we know that Andrew, a music teacher, does not have any students at the moment, but Andrew himself mistakenly thinks that he has one girl student.

a. According to Andrew$_j$, his$_j$ student$_i$ pushes herself$_i$
b. *According to Andrew$_j$, his$_j$ student$_i$ pushes himself$_i$.

As indicated in (70-a)-(70-b), we may only refer to the imaginary female student of Andrew's with a feminine pronoun. The use of a feminine pronoun is accounted for by assuming that "his$_j$ student$_i$" is in the scope of the intensional operator "according to Andrew" and is a quantificational DP introducing alternative assignments parameterized to a modal component that assigns a belief world of Andrew's to (the plain variable corresponding to) the variable $x_i^f$ translating the pronoun "herself$_i$". In particular, let's assume that the LF of (70-a) is given in (71) below, where "the" is the definite description operator (so, the LF representation of "his$_j$ student$_i$" is roughly the same as that of "the student$_i$ of his$_j$"):

(71) According to Andrew$_j$, [the x$_i$ [he$_{j[+gen]}$ student$_i$] [t$_i$ pushes herself$_i$]]

Moreover, let's assume that an indexed proper name $\alpha_j$ is translated as a variable "$x_j^c$" whose denotation is defined only in case the assignment assigns to "$x_j$" the individual rigidly denoted by the constant "$c$" translating $\alpha$:[9]

(72) $\left[\left[x_j^c\right]\right]_{M,c,g^s,w,t} = g^s(x_j)$ if $g^s(x_j) = [\![c]\!]_{M,c,g^s,w,t}$, and it's undefined otherwise.

We may now assume that LF (71) is translated as (73) (where R is a free variable translating [+*gen*] which denotes a contextually salient relation)[10] and the interpretation of "the" is specified as in (74):

(73) $B_{x_j^a}$ $(the\ x_i\ (student(x_i) \wedge R(x_j^a, x_i))\ push(x_i^f, x_i))$

(74) a. $[\![the\ \nu\ \Phi\Psi]\!]_{M,c,g^s,w,t}$ is defined only if
(i) $[\![\Phi]\!]_{M,c,g'^{s[\nu\to w]},w,t} = 1$ for exactly one $g'^{s[\nu\to w]}$ such that $g'^{s[\nu\to w]}[\nu]g^s$ and
(ii) $[\![\Psi]\!]_{M,c,g'^{s[\nu\to w]},w,t}$ is defined for every $g'^{s[\nu\to w]}$such that $g'^{s[\nu\to w]}[\nu]g^s$ and $[\![\Phi]\!]_{M,c,g'^{s[\nu\to w]},w,t} = 1$.

b. if $[\![the\ \nu\ \Phi\Psi]\!]_{M,c,g^s,w,t}$ is defined, then:
$[\![the\,\nu\ \Phi\Psi]\!]_{M,c,g^s,w,t} = 1$ if $[\![\Psi]\!]_{M,c,g'^{s[\nu\to w]},w,t} = 1$ for every $g'^{s[\nu\to w]}$ such that $g'^{s[\nu\to w]}[\nu]g^s$ and $[\![\Phi]\!]_{M,c,g'^{s[\nu\to w]},w,t} = 1$; otherwise $[\![the\,\nu\ \Phi\Psi]\!]_{M,c,g^s,w,t} = 0$.

According to these rules, the denotation of (73) is defined only if every student in Andrew's belief worlds is female in those worlds, since the oper-

[9]In particular, we take it that the translation of indexed NPs containing proper names works as in (i) below (where "$a$" is the constant translating the lexical item "Andrew" and "$x_i^a$" a presuppositional variable whose denotation is only defined in case the variable assignment assigns to "$x_i$" the individual rigidly denoted by the constant "$a$"):

(i)

$\mathrm{NP}_i \Rightarrow x_i^a$
|
$\mathrm{N} \Rightarrow a$
|
Andrew $\Rightarrow a$

Since we propose that indexed proper names are translated as (a particular kind of) variables, we assume that the option of binding them is either ruled out on pragmatic grounds (having to do with the definedness condition on the variables translating them, which anchors the value of the variable to a fixed individual) or by independent syntactic principles on coindexing.

[10]For an analysis of possessive NPs based on this idea, see Partee (1984, 1997).

ator "*the*", being in the scope of the quantifier over possible worlds "$B_{x_j^a}$", requires the formula "$push(x_i^f, x_i)$" to be defined for every assignment minimally different from the context assignment that assigns to "$x_i$" an individual who is a student of Andrew's in Andrew's belief worlds. Clearly, "$push(x_i^f, x_i)$" cannot be defined for any such assignment unless any student of Andrew's is female in Andrew's belief worlds. Since this is how Andrew's belief worlds are in the context at hand, (70-a) is predicted to be fine under the *de dicto* reading in (73).

On the other hand, the *de dicto* interpretation of (70-b), carried by translation (75) below, is predicted to be infelicitous. Indeed, since in Andrew's belief worlds any student of Andrew's is female, "$push(x_i^m, x_i)$" is undefined for every assignment that assigns to "$x_i$" an individual who is a student of Andrew 's in Andrew's belief worlds.

(75) $B_{x_j^a}$ $(the\ x_i\ (student(x_i) \wedge R(x_j^a, x_i))\ push(x_i^m, x_i))$

Notice, finally, that the *de re* interpretations of (70-a)-(70-b), given in (76)-(77), are ruled out in the context described in (70), since they require that there actually exist a student of Andrew's, contrary to what we know.

(76) $the\ x_i\ (student(x_i) \wedge R(x_j^a, x_i))(B_{x_j^a}\ push(x_i^f, x_i))$

(77) $the\ x_i\ (student(x_i) \wedge R(x_j^a, x_i))(B_{x_j^a}\ push(x_i^m, x_i))$

Thus, our proposal correctly predicts the contrast in (70-a)-(70-b).

A problem for our account is raised, on the other hand, by case (78), described by Yanovich (2010):

(78) Context: Smith College, one of the Five Colleges of Western Massachusetts, is a women's college. Imagine that Smith has recently gone coed, but not everyone knows about it yet, and Beth reads a letter to some newspaper by a Smith alumna who thinks that Smith is still a women's college. At the same time, Beth already knows that Smith is coed now.

a. This alumna strongly believes it should be made an absolute principle that every Smith College student$_i$ meet her$_i$ adviser at least twice a week.

As Yanovich points out, (78-a) is not felicitous if uttered by Beth, who believes that Smith is coed. This indicates that the presupposition of the pronoun "her" cannot be satisfied in the alumna's belief worlds, but must be satisfied in the world of the context of utterance. According to our account, (78-a) is in principle ambiguous between a *de dicto* reading, in which the quantifier "every Smith College student$_i$" is in the scope of "believe", and a *de re* reading, in which the quantifier is outside the scope of "believe" (further types of ambiguities are in principle possible if we consider different possible scopes of the NP "her$_i$ adviser" with respect to the intensional verb). Under the *de dicto* reading of the quantifier, we predict that the denotation of (78-a) is defined in the given context only if, in the alumna's belief worlds, every Smith college student is female. Thus, under the *de dicto* reading of the quantifier, (78-a) does not presuppose that every Smith college student is female in the world of the context of utterance, contrary to what seems to be the case. Both Yanovich and Sudo suggest that this is due to the fact that the quantifier in (78-a) is read *de re*, but this suggestion raises the question of why the *de re* reading should be forced.[11] Notice, moreover, that it is not obvious how to represent the desired *de re* reading in this case: if the quantifier "every Smith College student$_i$" is given wide scope with respect to the intensional verb, the reading we obtain is a distributive one by which the alumna has a singular belief about each Smith college student, something which is clearly not intended by (78-a) in the given context. So, we leave (78-a) as an open problem.

### 9.2 Anaphoric pronouns with non c-commanding antecedents

So far, we only considered cases in which third person pronouns are either non anaphoric and their interpretation is provided by the extra-linguistic context of utterance or bound by c-commanding quantifiers. How does the theory fare with pronouns anaphoric to non c-commanding antecedents?

Consider the conditionals in (79), based on Stalnaker (1988):

(79) a. lf a woman$_1$ had proposed the theory Copernicus proposed, she$_1$ would have been ignored.
b. lf Copernicus$_1$ hadn't existed, we would not praise him$_1$ now.

In (79-a), the pronoun "she$_1$" in the consequent is construed with the non c-commanding indefinite "a woman$_1$" in the antecedent. In (79-b), the pronoun "him$_1$" in the consequent is construed with the non c-commanding antecedent "Copernicus$_1$" in the antecedent. As Stalnaker observes, the pronoun in the consequent of (79-a) refers to an individual who only inhabits the counterfactual world(s) in which the antecedent is true, while the

[11] Similar cases in which wide scope is forced for descriptions in the scope of attitude verbs are discussed in Heim (1992).

pronoun in the consequent of (79-b) refers to a real world individual. Let's see how our analysis copes with these data.

Consider (79-a) first. As is well-known, the anaphoric relation in (79-a) is either analysed as an instance of binding (Kamp 1981, Heim 1982, Groenendijk and Stokhof 1991 and others) or as an instance of e-type anaphora (Evans 1977, 1980 and others). In the latter case, the pronoun is analysed as a definite description. Suppose we adopt the e-type analysis. Then, in (79-a) the pronoun "$\text{she}_1$" is presumably reconstructed at LF as the description "the woman who proposed $t_2$", where $t_2$ denotes the theory proposed by Copernicus in the actual world. Moreover, the description "the theory Copernicus proposed" in (79-a) is plausibly given wide scope with respect to the conditional operator, since there is no theory Copernicus proposed in the counterfactual world(s) selected by the antecedent clause. Thus, (79-a) will be represented as in (80) at LF (ignoring tense) and translated as in (81) (where "W" translates the predicate "woman", "P" the predicate "propose", "I" the predicate "ignore" and "K" the complex predicate "theory Copernicus proposed"):

(80) $\text{the}_2$ [theory Copernicus proposes]$_2$ [if [$\text{a}_1$ [woman]$_1$ [$t_1$ proposes $\text{t}_2$]], [$\text{the}_1$ [woman who proposes $\text{t}_2$]$_1$ [$t_1$ is ignored]]]

(81) $\textit{the } x_2\ [K(x_2)][\textit{if}[a\ x_1\ W(x_1)\ P(x_2, x_1)]$ $[\textit{the } x_1[W(x_1) \land P(x_2, x_1)][I(x_1)]]]$

Let's assume the following interpretation for the conditional operator *if* (since the choice of the particular analysis of conditionals does not bear on our problem, we adopt the simpler theory proposed by Stalnaker 1968):

(82) a. $[\![\textit{if}\ \Phi\Psi]\!]_{c,g^s,w,t}$ is defined only if $[\![\Psi]\!]_{c,g^s,w',t}$ is defined, where $w'$ is the world closest to $w$ such that $[\![\Phi]\!]_{c,g^s,w',t} = 1$.

b. if $[\![\textit{if}\ \Phi\Psi]\!]_{c,g^s,w,t}$ is defined, then: $[\![\textit{if}\ \Phi\Psi]\!]_{c,g^s,w,t} = 1$ if $[\![\Psi]\!]_{c,g^s,w',t} = 1$, where $w'$ is the world closest to $w$ such that $[\![\Phi]\!]_{c,g^s,w',t} = 1$; otherwise $[\![\textit{if}\ \Phi\Psi]\!]_{c,g^s,w,t} = 0$.

E-type theories of anaphora usually assume that indefinite DPs of the form [$_{\text{DP}}$ a(n) NP] are quantificational and introduce an existential quantifier. In our terms, this assumption may be stated thus (we also assume that the definedness condition of indefinites, unlike that of universal quantifiers, gives rise to existential presuppositions):[12]

[12]For the assumption concerning existential presuppositions of indefinites, see Sudo

(83) a. $[\![a\,\nu\ \Phi\Psi]\!]_{M,c,g^s,w,t}$ is defined only if $[\![\Psi]\!]_{M,c,g'^{s[\nu\rightarrow w]},w,t}$ is defined for some $g'^{s[\nu\rightarrow w]}$ such that $g'^{s[\nu\rightarrow w]}[\nu]g^s$ and $[\![\Phi]\!]_{M,c,g'^{s[\nu\rightarrow w]},w,t}$ $= 1$.

b. if $[\![a\,\nu\ \Phi\Psi]\!]_{M,c,g^s,w,t}$ is defined, then:
$[\![a\,\nu\ \Phi\Psi]\!]_{M,c,g^s,w,t} = 1$ if $[\![\Psi]\!]_{M,c,g'^{s[\nu\rightarrow w]},w,t} = 1$ for some $g'^{s[\nu\rightarrow w]}$ such that $g'^{s[\nu\rightarrow w]}[\nu]g^s$ and $[\![\Phi]\!]_{M,c,g'^{s[\nu\rightarrow w]},w,t} = 1$; otherwise $[\![a\,\nu\ \Phi\Psi]\!]_{M,c,g^s,w,t} = 0$.

By the analysis of definite descriptions proposed in (74), we expect, what is correct, that the description corresponding to the pronoun "she$_1$" in (79-a) should be satisfied in the closest world in which a woman proposed the theory that Copernicus actually proposed:

(84) $[\![(81)]\!]_{M,c,c^s_g,c_w,c_t}$ is defined only if
(i) $[\![K(x_2)]\!]_{M,c,g'^{s[x_2\rightarrow c_w]},c_w,c_t}$=1 for exactly one $g'^{s[x_2\rightarrow c_w]}$ such that $g'^{s[x_2\rightarrow c_w]}[x_2]c^s_g$ and
(ii) $[\![\mathit{if}[a\ x_1\ W(x_1)P(x_2,x_1)][\mathit{the}\ x_1[W(x_1)\wedge P(x_2,x_1)][I(x_1)]]]\!]_{M,c,g'^{s[x_2\rightarrow c_w]},c_w,c_t}$
is defined for every $g'^{s[x_2\rightarrow c_w]}$ such that
$g'^{s[x_2\rightarrow c_w]}[x_2]c^s_g$ and $[\![K(x_2)]\!]_{M,c,g'^{s[x_2\rightarrow c_w]},c_w,c_t}$=1
only if (i) and for every $g'^{s[x_2\rightarrow c_w]}$ such that $g'^{s[x_2\rightarrow c_w]}[x_2]c^s_g$ and $[\![K(x_2)]\!]_{M,c,g'^{s[x_2\rightarrow c_w]},c_w,c_t}$=1,
$[\![\mathit{the}\ x_1[W(x_1)\wedge P(x_2,x_1)][I(x_1)]]\!]_{M,c,g'^{s[x_2\rightarrow c_w]},w',c_t}$ is defined, where $w'$ is the world closest to $c_w$ in which
$[\![a\ x_1\ W(x_1)P(x_2,x_1)]\!]_{M,c,g'^{s[x_2\rightarrow c_w]},w',c_t} = 1$
only if (i) and for every $g'^{s[x_2\rightarrow c_w]}$ such that $g'^{s[x_2\rightarrow c_w]}[x_2]c^s_g$ and $[\![K(x_2)]\!]_{M,c,g'^{s[x_2\rightarrow c_w]},c_w,c_t} = 1$,
$[\![W(x_1)\wedge P(x_2,x_1)]\!]_{M,c,g''^{s[x_2\rightarrow c_w,x_1\rightarrow w']},w',c_t} = 1$
for exactly one $g''^{s[x_2\rightarrow c_w,x_1\rightarrow w']}$ such that $g''^{s[x_2\rightarrow c_w,x_1\rightarrow w']}[x_1]g'^{s[x_2\rightarrow c_w]}$ and $[\![I(x_1)]\!]_{M,c,g''^{s[x_2\rightarrow c_w,x_1\rightarrow w']},w',c_t}$ is defined for every $g''^{s[x_2\rightarrow c_w,x_1\rightarrow w']}$ such that $g''^{s[x_2\rightarrow c_w,x_1\rightarrow w']}[x_1]g'^{s[x_2\rightarrow c_w]}$ and
$[\![W(x_1)\wedge P(x_2,x_1)]\!]_{M,c,g''^{s[x_2\rightarrow c_w,x_1\rightarrow w']},w',c_t} = 1$
only if there is exactly one theory Copernicus proposes in $c_w$ and in the world $w'$ closest to $c_w$ in which a woman proposes the theory Copernicus proposes in $c_w$, there is exactly one woman who proposes the theory Copernicus proposes in $c_w$.

2012, 2013b and references cited therein.

Now let's suppose instead that the anaphoric relation in (79-a) is an instance of binding. We will sketch one such analysis based on the assumption that indefinites are non quantificational and are translated as open formulae (Heim 1982, Kamp 1981).[13] Let's assume with Heim that, at LF, indefinite DPs copy their index on the conditional operator. In this case, (79-a) will be represented at LF as (85) (ignoring tense) and translated as (86):

(85) the$_2$ [theory Copernicus proposes]$_2$ [if$_1$ [a [woman]$_1$ [t$_1$ proposes t$_2$]], [she$_1$ is ignored]]

(86) $\textit{the}\ x_2\ [K(x_2)][\textit{if}_{x_1}[W(x_1) \wedge P(x_2, x_1)][I(x_1^f)]]$

The interpretation of the conditional operator may now be stated as in (87) below (when no indices are copied on the *if*-operator, clause (87) reduces to (82)):[14]

(87) a. $\left[\!\left[\textit{if}_{\nu_i \ldots \nu_j}\ \Phi\Psi\right]\!\right]_{c,g^s,w,t}$ is defined only if $[\![\Psi]\!]_{c,{g'}^{s[\nu_i \to w', \ldots, \nu_j \to w']},w',t}$ is defined for every $w'$ which is the world closest to $w$ such that $[\![\exists \nu_i \ldots \nu_j \Phi]\!]_{c,g^s,w',t} = 1$ and for every ${g'}^{s[\nu_i \to w', \ldots, \nu_j \to w']}$ such that ${g'}^{s[\nu_i \to w', \ldots, \nu_j \to w']}[\nu_i, \ldots, \nu_j]g^s$ and $[\![\Phi]\!]_{c,{g'}^{s[\nu_i \to w', \ldots, \nu_j \to w']},w',t}$=1.

b. if $\left[\!\left[\textit{if}_{\nu_i \ldots \nu_j}\ \Phi\Psi\right]\!\right]_{c,g^s,w,t}$ is defined, then: $\left[\!\left[\textit{if}_{\nu_i \ldots \nu_j}\ \Phi\Psi\right]\!\right]_{c,g^s,w,t} = 1$ if $[\![\Psi]\!]_{c,{g'}^{s[\nu_i \to w', \ldots, \nu_j \to w']},w',t} = 1$ for every $w'$ which is the world closest to $w$ such that $[\![\exists \nu_i \ldots \nu_j \Phi]\!]_{c,g^s,w',t} = 1$ and for every ${g'}^{s[\nu_i \to w', \ldots, \nu_j \to w']}$ such that ${g'}^{s[\nu_i \to w', \ldots, \nu_j \to w']}[\nu_i, \ldots, \nu_j]g^s$ and $[\![\Phi]\!]_{c,{g'}^{s[\nu_i \to w', \ldots, \nu_j \to w']},w',t}$ = 1; otherwise $\left[\!\left[\textit{if}_{\nu_i \ldots \nu_j}\ \Phi\Psi\right]\!\right]_{c,g^s,w,t} = 0$.

[13] Another option, which we don't pursue here, is that indefinites introduce dynamic existential quantifiers, as in Groenendijk and Stokhof (1991) and others.

[14] We assume that the denotation of "$\exists \nu_i \ldots \nu_j \Phi$" is defined as follows:

(i) a. $[\![\exists \nu_i \ldots \nu_j \Phi]\!]_{M,c,g^s,w,t}$ is defined only if $[\![\Phi]\!]_{M,c,{g'}^{s[\nu_i \to w, \ldots, \nu_j \to w]},w,t}$ is defined for some ${g'}^{s[\nu_i \to w, \ldots, \nu_j \to w]}$ such that ${g'}^{s[\nu_i \to w, \ldots, \nu_j \to w]}[\nu_i, \ldots, \nu_j]g^s$.

b. if $[\![\exists \nu\ \Phi]\!]_{M,c,g^s,w,t}$ is defined, then: $[\![\exists \nu_i \ldots \nu_j \Phi]\!]_{M,c,g^s,w,t} = 1$ if $[\![\Phi]\!]_{M,c,{g'}^{s[\nu_i \to w, \ldots, \nu_j \to w]},w,t} = 1$ for some ${g'}^{s[\nu_i \to w, \ldots, \nu_j \to w]}$ such that ${g'}^{s[\nu_i \to w, \ldots, \nu_j \to w]}[\nu_i, \ldots, \nu_j]g^s$; otherwise $[\![\exists \nu\ \Phi]\!]_{M,c,g^s,w,t} = 0$.

Again, by this analysis, we correctly predict that the descriptive content of the pronoun "she$_1$" in (79-a) should be satisfied in the closest world in which a woman proposed the theory that Copernicus actually proposed:

(88) $[\![(86)]\!]_{M,c,c^s_g,c_w,c_t}$ is defined only if
(i) $[\![K(x_2)]\!]_{M,c,g'^{s[x_2\to c_w]},c_w,c_t}$=1 for exactly one $g'^{s[x_2\to c_w]}$ such that $g'^{s[x_2\to c_w]}[x_2]c^s_g$ and
(ii) $\left[\!\!\left[if_{x_1}[W(x_1)\wedge P(x_2,x_1)][I(x^f_1)]\right]\!\!\right]_{M,c,g'^{s[x_2\to c_w]},c_w,c_t}$ is defined for every $g'^{s[x_2\to c_w]}$ such that $g'^{s[x_2\to c_w]}[x_2]c^s_g$ and
$[\![K(x_2)]\!]_{M,c,g'^{s[x_2\to c_w]},c_w,c_t}$=1
only if (i) and for every $g'^{s[x_2\to c_w]}$ such that $g'^{s[x_2\to c_w]}[x_2]c^s_g$ and
$[\![K(x_2)]\!]_{M,c,g'^{s[x_2\to c_w]},c_w,c_t}$=1, $\left[\!\!\left[I(x^f_1)\right]\!\!\right]_{M,c,g''^{s[x_2\to c_w,x_1\to w']},w',c_t}$ is defined for every $w'$ which is the world closest to $c_w$ such that
$[\![\exists\nu_i\ldots\nu_j\Phi]\!]_{c,g'^{s[x_2\to c_w]},w',t}=1$ and every $g''^{s[x_2\to c_w,x_1\to w']}$ such that $g''^{s[x_2\to c_w,x_1\to w']}[x_1]g'^{s[x_2\to c_w]}$ and
$[\![W(x_1)\wedge P(x_2,x_1)]\!]_{M,c,g''^{s[x_2\to c_w,x_1\to w']},w',c_t}=1$
only if (i) and for every $g'^{s[x_2\to c_w]}$ such that $g'^{s[x_2\to c_w]}[x_2]c^s_g$ and
$[\![K(x_2)]\!]_{M,c,g'^{s[x_2\to c_w]},c_w,c_t}$=1, $g''^{s[x_2\to c_w,x_1\to w']}(x_1)$ is female in $w'$ for every $w'$ which is the world closest to $c_w$ such that
$[\![\exists\nu_i\ldots\nu_j\Phi]\!]_{c,g'^{s[x_2\to c_w]},w',t}=1$ and every $g''^{s[x_2\to c_w,x_1\to w']}$ such that $g''^{s[x_2\to c_w,x_1\to w']}[x_1]g'^{s[x_2\to c_w]}$ and
$[\![W(x_1)\wedge P(x_2,x_1)]\!]_{M,c,g''^{s[x_2\to c_w,x_1\to w']},w',c_t}=1$
only if there is exactly one theory Copernicus proposes in $c_w$ and for every individual and every world $w'$ such that the individual is a woman who proposes in $w'$ the theory Copernicus proposes in $c_w$ and $w'$ is the world closest to $c_w$ in which a woman proposes the theory Copernicus proposes in $c_w$, the individual is female in $w'$.

Consider now conditional (79-b):

(79) b. If Copernicus$_1$ hadn't existed, we would not praise him$_1$ now.

According to our assumption about proper names in the previous section, (79-b) is translated as (89) (for simplicity, we ignore tense and the time indexical "now", and we assume that "$k$" is the individual constant translating the proper name "Copernicus"):

(89) $\textit{if} \sim E(x_1^k) \sim P(we, x_1^m)$

Assuming interpretation (82) for the conditional operator, we derive the definedness conditions in (90-a) for (89):

(90) a. $[[\textit{if} \sim E(x_1^k) \sim P(we, x_1^m)]]_{M,c,c_g^s,c_w,c_t}$ is defined only if $[\![\sim P(we, x_1^m)]\!]_{M,c,c_g^s,w',c_t}$ is defined, where $w'$ is the world closest to $c_w$ such that $[[\sim E(x_1^k)]]_{M,c,c_g^s,w',c_t}$=1 only if $c_g^s(x_1)$ is male in $c_w = s(x_1)$ and $c_g^s(x_1)$ is identical to Copernicus.

b. if $[[\textit{if} \sim E(x_1^k) \sim P(we, x_1^m)]]_{M,c,c_g^s,c_w,c_t}$ is defined, then $[[\textit{if} \sim E(x_1^k) \sim P(we, x_1^m)]]_{M,c,c_g^s,c_w,c_t} = 1$ if $[\![\sim P(we, x_1^m)]\!]_{M,c,c_g^s,w',c_t}$ =1 , where $w'$ is the world closest to $c_w$ such that $[[\sim E(x_1^k)]]_{M,c,c_g^s,w',c_t}$=1 if $c_g^s(x_1)$ is male in $c_w = s(x_1)$, we do not praise $c_g^s(x_1)$ in $w'$, where $w'$ is the world closest to $c_w$ such that $c_g^s(x_1)$ is identical to Copernicus and $c_g^s(x_1)$ does not inhabit $w'$.

According to (90-a), for formula (89) translating (79-b) to be defined, the contextual assignment must assign to the pronoun "him$_1$" an individual who is male in the world of the context and identical to Copernicus. Since Copernicus is a man in the context of utterance of (79-b), the condition is met.

If the above observations are correct, our proposal accounts for the interpretation of anaphoric pronouns with non c-commanding antecedents in the conditionals in (79): the behaviour of these pronouns in (79) is consistent with our assumption concerning the role of quantifiers in shifting the modal component of the assignment.

Notice, by the way, that the account we propose for the behavior of pronouns anaphoric to proper names can also explain cases in which pronouns occur in the scope of attitude verbs while being anaphoric to proper names. Consider for instance the following discourse, based on Sharvit (2008):

(91) John$_i$ didn't realize that Bill$_j$ was male. John thought that he$_j$*she$_j$ liked him$_i$.

Sharvit's observation is that it is odd to use "she" in this discourse. Our proposal predicts the oddness of the female pronoun in (91), since it requires that the descriptive content of "she$_j$" be satisfied by Bill in the world of the context of utterance of (91).

We conclude by pointing out an open problem for our proposal. Consider case (92), based on Yanovich (2010):

(92) Context: The Russian name "Sasha" can be used for both male and female individuals. Suppose that I plan to visit some old friends of mine. I know that they have a kid and that the name of the kid is "Sasha", but I do not know whether it is a girl or a boy.

a. ??Tomorrow, I'll see Sasha$_1$. I'll kiss him$_1$.

b. ??Tomorrow, I'll see Sasha$_1$. I'll kiss her$_1$.

Our account can explain the infelicity of (92-a)-(92-b) in the following way. Suppose that (92-a)-(92-b) are translated, respectively, as (93-a)-(93-b) (ignoring the tense and the time adverb):

(93) a. $visit(x_1^s, I) \wedge kiss(x_1^m, I)$

b. $visit(x_1^s, I) \wedge kiss(x_1^f, I)$

According to our theory, (93-a)-(93-b) are true in a context if they are true with respect to the assignment of the context, false if they are false with respect to that assignment. No matter how we specify the definedness conditions for conjoined formulae, (93-a) is only defined for assignments that assign to the variable $x_1$ an individual who is male and is identical to Sasha in the world of the context, while (93-b) is only defined for assignments that assign to the variable $x_1$ an individual who is female and is identical to Sasha in the world of the context. Based on Soames (1989) and Sudo (2012), we introduce the following bridge principle relating the semantic notion of presupposition to the pragmatic one:[15]

(94) If, in order for the denotation of $S$ to be defined in a context $c$, $p$ must be the case in the world of $c$, then, for $S$ to be felicitously uttered in $c$, the conversational background of $c$ must entail $p$.

Since, in the context described in (92), the sex of Sasha is not known, the conversational background entails neither that Sasha is female nor that Sasha is male, thus (92-a) and (92-b) are now predicted to be infelicitous in that context.[16]

[15] The same principle was implicitly at work in the explanation we proposed for the infelicity of (51) and (65).

[16] More generally, the infelicity of (92-a)-(92-b) uttered in the context described in (92) may be seen as following from a precondition for the illocutionary act of assertion. According to our theory, (93-a) is true in a context only if Sasha is male in the world of

Consider, however, the conditionals in (95), uttered in the same context:

(95) a. If $\text{Sasha}_1$ is male, I'll buy $\text{him}_1$ a doll.
b. If $\text{Sasha}_2$ is female, I'll buy $\text{her}_2$ a toy car.

Sentences (95-a)-(95-b) are both felicitous in that context. Yet, given our semantics, these sentences should behave like conditional (79-b) above. In particular, (95-a) should only be defined for assignments that assign to the variable $x_1$ an individual who is male and is identical to Sasha in the world of the context, and (95-b) should only be defined for assignments that assign to the variable $x_2$ an individual who is female and is identical to Sasha in the world of the context. Thus, for (95-a) to be defined, Sasha must be male in the world of the context and, for (95-b) to be defined, Sasha must be female in the world of the context. Since, in the context described in (92), we do not know Sasha's sex, the conversational background of the context fails to entail that Sasha is male and fails to entail that Sasha is female, thus (95-a)-(95-b) are incorrectly predicted to be infelicitous. We leave this as an open problem for our account.

## 10 Conclusions

Kaplan's (1977) goal was to provide a semantics for demonstrative uses of third person pronouns and other indexicals. Bound variable uses of third person pronouns were explicitly excluded from his investigation. Indeed, Kaplan suggested that demonstrative and bound variable uses of "he" involve distinct lexical items that happen to be homonyms:

> ...I began my investigations by asking what is said when a speaker points at someone and says, "He is suspicious". The word 'he', so used, is a demonstrative...
>
> The group of words for which I propose a semantical theory includes the pronouns 'I', 'my', 'you', 'he', 'his', 'she', 'it', the

the context, while (93-b) is true in a context only if Sasha is female in the world of the context. Searle (1974) suggests that assertion must conform to this preparatory rule: the speaker must be in a position to provide evidence or reasons for the truth of the sentence asserted. Applied to (92), this means that, if a speaker asserts (92-a), then she must be in a position to provide evidence that Sasha is male and, if a speaker asserts (92-b), then she must be in a position to provide evidence that Sasha is female. Given that in the context described in (92) the sex of Sasha is not known, neither (92-a) nor (92-b) can be asserted in that context, since the speaker has no evidence that either one is true. A similar account may be proposed for (51) and (65).

> demonstrative pronouns ‘that’, ‘this’, the adverbs ‘here’, ‘now’, ‘tomorrow’, ‘yesterday’, the adjectives ‘actual’, ‘present’, and others. These words have uses other than those in which I am interested (or, perhaps, depending on how you individuate words, we should say that they have homonyms in which I am not interested). For example, the pronouns ‘he’ and ‘his’ are used not as demonstratives but as bound variables in
>
>> For what is a man profited, if he shall gain the whole world, and lose his own soul?
>
> (Kaplan 1977, pp. 489-90)

As we pointed out at the start, the hypothesis that demonstrative and bound variable uses of “he” involve distinct lexical items leaves unexplained why in language after language the same phonological word is used both as a demonstrative and as a bound variable. This observation provides a good reason not to concede the homonym hypothesis, or at least not to concede it without putting up a fight. In this paper, we assumed that Kaplan, when uttering a demonstrative “he”, and the Son, nay King James’s translator, when uttering a bound pronoun “he”, were uttering *the same word* both from a phonological and from a semantic point of view, not just homonyms.

We explored an account of the semantics of this word which does not require quantifiers to be monsters and which is based on the idea that variable assignments occur both as coordinates of the context and as coordinates of the circumstance of evaluation. According to this account, non anaphoric free third-person pronouns are no longer indexical in Kaplan’s sense: as for its reference, a third-person pronoun depends on a coordinate of the circumstance of evaluation, i.e. on the variable assignment $g^s$ of the circumstance, and not directly on any aspect of the context. The fact that its value ends up being determined by the context is a byproduct of the definition of truth in a context, that equates the variable assignment of the context with the variable assignment of the circumstance. In MacFarlane’s (2009) terms, this amounts to saying that non anaphoric free third-person pronouns are *context sensitive*, since they have different denotations relative to different contexts of use, but not *indexical*, since their content does not vary from context to context. The fact that the denotation of third person pronouns depends on the assignment coordinate of the circumstance opens up the possibility that third person pronouns may not have a contextually determined reference whenever they are in the scope of operators that shift the assignment of the circumstance. We argued that quantifiers are such operators.

We proposed that, for an account of this sort to work properly (in particular, for it to avoid generating unwanted indexical presuppositions for bound pronouns), one should assume that variable assignments have a modal component, and thus they perform two tasks: not only do they assign individuals to variables but they also assign worlds to variables (that is, to each variable $\nu$ they associate information concerning the "modal localization" of the individual assigned to $\nu$). We tested the empirical coverage of the theory and we saw that it accounts for several core cases of interaction of pronouns with intensional operators. As it might be expected, we also found some cases in which the theory needs to be refined further.

## Acknowledgements

To be written.

# Appendix 1: The formal system

In this appendix, we state the formal system in its final form.

## The intensional language IL

### Symbols

$c_1$, $c_2$, $c_3$, ... (individual constants)

$x_1$, $x_2$, $x_3$, ... (plain variables)

$x_1^m$, $x_2^m$, $x_3^m$, ... (presuppositional variables)

$x_1^f$, $x_2^f$, $x_3^f$, ... (presuppositional variables)

$x_1^n$, $x_2^n$, $x_3^n$, ... (presuppositional variables)

$x_1^{c_1}$, $x_1^{c_2}$, $x_1^{c_3}$,... $x_2^{c_1}$, $x_2^{c_2}$, $x_2^{c_3}$, ... (presuppositional variables)

$P_1^1$, $P_2^1$, ..., $P_1^2$, $P_2^2$... (predicates)

$\wedge$, $\sim$, $\vee$, *every*, *the*, *a*, *if*, $\Diamond$, $\Box$, $B$, *believe*, $E$ (logical constants)

**Formulae** Let $\mathcal{V}$ be the set of plain variables and $\mathcal{V}^*$ the set of variables (plain and presuppositional).

1. If $\texttt{P}^n$ is an n-place predicate and $\tau_i, \ldots \tau_j$ are n terms (variables or constants), $\texttt{P}^n(\tau_i, \ldots \tau_j)$ is a wff.
2. If $\Phi$ and $\Psi$ are wffs, then $\ulcorner\sim \Phi\urcorner$, $\ulcorner\Phi \wedge \Psi\urcorner$, $\ulcorner\Phi \vee \Psi\urcorner$ $\ulcorner if\ \Phi\Psi\urcorner$, $\ulcorner\Diamond\Phi\urcorner$, $\ulcorner\Box\Phi\urcorner$ are wffs.
3. if $\Phi$ and $\Psi$ are wffs and $\nu \in \mathcal{V}$, $\ulcorner every\ \nu\ \Phi\Psi\urcorner$, $\ulcorner the\ \nu\ \Phi\Psi\urcorner$, $\ulcorner a\ \nu\ \Phi\Psi\urcorner$ are wffs.
4. If $\tau$ is a term and $\Phi$ is a wff, $\ulcorner B_\tau\Phi\urcorner$ is a wff.
5. If $\tau$ is a term and $\Phi$ is a wff, $\ulcorner believe(\tau, \Phi)\urcorner$ is a wff.
6. If $\tau$ is a term, $\ulcorner E(\tau)\urcorner$ is a wff.

**Models** A model for IL is a structure $M =< \mathcal{C}, \mathcal{W}, \mathcal{U}, \mathcal{T}, \mathcal{P}, \mathcal{I}, \mathcal{F} >$, where

1. $\mathcal{C}$ is a nonempty set (the set of contexts), where if $c \in \mathcal{C}$,
   - (i) $c_a \in \mathcal{U}$ (the agent of $c$)
   - (ii) $c_t \in \mathcal{T}$ (the time of $c$)
   - (iii) $c_p \in \mathcal{P}$ (the position of $c$)
   - (iv) $c_w \in \mathcal{W}$ (the world of $c$)
   - (v) $c_g^s \in \mathcal{U}^{\mathcal{V}}$ (the assignment of $c$), where $s \in \mathcal{W}^{\mathcal{V}}$ and $s(\nu) = c_w$ for every $\nu \in \mathcal{V}$.
   - (vi) $c_R \in \mathcal{W} \times \mathcal{W}$ (an accessibility relation).
2. $\mathcal{W}$ is a nonempty set (the set of worlds)
3. $\mathcal{U}$ is a nonempty set (the set of individuals)
4. $\mathcal{T}$ is a nonempty set (the set of times)
5. $\mathcal{P}$ is a nonempty set (the set of positions)
6. $\mathcal{I} \in \wp(\mathcal{U})^{\mathcal{W}}$ (a function that assigns to each world $w \in \mathcal{W}$ the set of individuals in $\mathcal{U}$ inhabiting world $w$)
7. $\mathcal{F}$ is a function that to every triple consisting of an n-place predicate $\mathtt{P}^n$, a world, and a time, assigns a set of $n$-tuples of members of $\mathcal{U}$, and to every individual constant assigns a member of $\mathcal{U}$.

**Denotation** The denotation of an expression is relative to a model, a context of utterance, and a circumstance of evaluation consisting of a world, a time, and a variable assignment $g^s$, where $g^s \in \mathcal{U}^{\mathcal{V}}$ and $s \in \mathcal{W}^{\mathcal{V}}$.

We use "$[\![\alpha]\!]_{M,c,g^s,w,t}$" as short for "the denotation of $\alpha$ in the context $c$ relative to the circumstance $< g^s, w, t >$".

We use "$g'^{s[\nu_i \rightarrow w,\ldots,\nu_j \rightarrow w']}[\nu_i, \ldots, \nu_j]g^s$" as short for "the assignment $g'^{s[\nu_i \rightarrow w,\ldots,\nu_j \rightarrow w']}$ is identical to $g^s$ except for the fact that (i) $g'^{s[\nu_i \rightarrow w,\ldots,\nu_j \rightarrow w']}$ may differ from $g^s$ because its modal component assigns the world $w$ to the variable $\nu_i$, … , and the world $w'$ to the variable $\nu_j$ and (ii) $g'^{s[\nu_i \rightarrow w,\ldots,\nu_j \rightarrow w']}$ may differ from $g^s$ for the individuals assigned to $\nu_i, \ldots, \nu_j$".

Here we specify the denotations for a selected set of expressions:

1. $[\![c_i]\!]_{M,c,g^s,w,t} = \mathcal{F}(c_i)$.
2. $[\![\mathtt{P}^n]\!]_{M,c,g^s,w,t} = \mathcal{F}(\mathtt{P}^n)(w)(t)$.

3. $[\![x_i]\!]_{M,c,g^s,w,t} = g^s(x_i)$, where $g^s(x_i) \in \mathcal{I}(s(x_i))$ (i.e., the individual $g^s(x_i)$ inhabits the world $s(x_i)$).

4. $[\![x_i^m]\!]_{M,c,g^s,w,t} = g^s(x_i)$ if $g^s(x_i)$ is human and male in $s(x_i)$, and it's undefined otherwise.

5. $\left[\!\left[x_i^f\right]\!\right]_{M,c,g^s,w,t} = g^s(x_i)$ if $g^s(x_i)$ is human and female in $s(x_i)$, and it's undefined otherwise.

6. $[\![x_i^n]\!]_{M,c,g^s,w,t} = g^s(x_i)$ if $g^s(x_i)$ is non human in $s(x_i)$, and it's undefined otherwise.

7. $[\![x_i^{c_i}]\!]_{M,c,g^s,w,t} = g^s(x_i)$ if $g^s(x_i) = [\![c_i]\!]_{M,c,g^s,w,t}$, and it's undefined otherwise.

8. Suppose $[\![\tau_i]\!]_{M,c,g^s,w,t}, \ldots, [\![\tau_j]\!]_{M,c,g^s,w,t}$ are defined.
   Then $[\![\mathtt{P}^n(\tau_i, \ldots, \tau_j)]\!]_{M,c,g^s,w,t} = 1$ if $< [\![\tau_i]\!]_{M,c,g^s,w,t}, \ldots, [\![\tau_j]\!]_{M,c,g^s,w,t} > \in \mathcal{F}(\mathtt{P}^n)(w)(t)$;
   $[\![\mathtt{P}^n(\tau_i, \ldots, \tau_j)]\!]_{M,c,g^s,w,t} = 0$ if $< [\![\tau_i]\!]_{M,c,g^s,w,t}, \ldots, [\![\tau_j]\!]_{M,c,g^s,w,t} > \notin \mathcal{F}(\mathtt{P}^n)(w)(t)$.

9. (a) $[\![every\ \nu\ \Phi\Psi]\!]_{M,c,g^s,w,t}$ is defined only if $[\![\Psi]\!]_{M,c,g'^{s[\nu\to w]},w,t}$ is defined for every $g'^{s[\nu\to w]}$ such that $g'^{s[\nu\to w]}[\nu]g^s$ and $[\![\Phi]\!]_{M,c,g'^{s[\nu\to w]},w,t} = 1$.
   (b) if $[\![every\ \nu\ \Phi\Psi]\!]_{M,c,g^s,w,t}$ is defined, then:
   $[\![every\ \nu\ \Phi\Psi]\!]_{M,c,g^s,w,t} = 1$ if $[\![\Psi]\!]_{M,c,g'^{s[\nu\to w]},w,t} = 1$ for every $g'^{s[\nu\to w]}$ such that $g'^{s[\nu\to w]}[\nu]g^s$ and $[\![\Phi]\!]_{M,c,g'^{s[\nu\to w]},w,t} = 1$;
   otherwise $[\![every\ \nu\ \Phi\Psi]\!]_{M,c,g^s,w,t} = 0$.

10. (a) $[\![the\ \nu\ \Phi\Psi]\!]_{M,c,g^s,w,t}$ is defined only if
    (i) $[\![\Phi]\!]_{M,c,g'^{s[\nu\to w]},w,t} = 1$ for exactly one $g'^{s[\nu\to w]}$ such that $g'^{s[\nu\to w]}[\nu]g^s$ and
    (ii) $[\![\Psi]\!]_{M,c,g'^{s[\nu\to w]},w,t}$ is defined for every $g'^{s[\nu\to w]}$ such that $g'^{s[\nu\to w]}[\nu]g^s$ and $[\![\Phi]\!]_{M,c,g'^{s[\nu\to w]},w,t} = 1$.
    (b) if $[\![the\ \nu\ \Phi\Psi]\!]_{M,c,g^s,w,t}$ is defined, then:
    $[\![the\ \nu\ \Phi\Psi]\!]_{M,c,g^s,w,t} = 1$ if $[\![\Psi]\!]_{M,c,g'^{s[\nu\to w]},w,t} = 1$ for every $g'^{s[\nu\to w]}$ such that $g'^{s[\nu\to w]}[\nu]g^s$ and $[\![\Phi]\!]_{M,c,g'^{s[\nu\to w]},w,t} = 1$;
    otherwise $[\![the\ \nu\ \Phi\Psi]\!]_{M,c,g^s,w,t} = 0$.

11. (a) $[\![a\ \nu\ \Phi\Psi]\!]_{M,c,g^s,w,t}$ is defined only if $[\![\Psi]\!]_{M,c,g'^{s[\nu\to w]},w,t}$ is defined for some $g'^{s[\nu\to w]}$ such that $g'^{s[\nu\to w]}[\nu]g^s$ and $[\![\Phi]\!]_{M,c,g'^{s[\nu\to w]},w,t}$ $= 1$.
    (b) if $[\![a\ \nu\ \Phi\Psi]\!]_{M,c,g^s,w,t}$ is defined, then:
    $[\![a\ \nu\ \Phi\Psi]\!]_{M,c,g^s,w,t} = 1$ if $[\![\Psi]\!]_{M,c,g'^{s[\nu\to w]},w,t} = 1$ for some $g'^{s[\nu\to w]}$ such that $g'^{s[\nu\to w]}[\nu]g^s$ and $[\![\Phi]\!]_{M,c,g'^{s[\nu\to w]},w,t} = 1$;
    otherwise $[\![a\ \nu\ \Phi\Psi]\!]_{M,c,g^s,w,t} = 0$.

12. (a) $[\![\Diamond\varphi]\!]_{M,c,g^s,w,t}$ is defined only if $[\![\varphi]\!]_{M,c,g^s,w',t}$ is defined for all $w' \in \mathcal{W}$ such that $w\, c_R\, w'$.
    (b) if $[\![\Diamond\varphi]\!]_{M,c,g^s,w,t}$ is defined, then:
    $[\![\Diamond\varphi]\!]_{M,c,g^s,w,t} = 1$ if $[\![\varphi]\!]_{M,c,g^s,w',t} = 1$, for some $w' \in \mathcal{W}$ such that $w\, c_R\, w'$;
    $[\![\Diamond\varphi]\!]_{M,c,g^s,w,t} = 0$ if $[\![\varphi]\!]_{M,c,g^s,w',t} = 0$, for all $w' \in \mathcal{W}$ such that $w\, c_R\, w'$.

13. (a) $[\![\textit{if}\ \Phi\Psi]\!]_{c,g^s,w,t}$ is defined only if $[\![\Psi]\!]_{c,g^s,w',t}$ is defined, where $w'$ is the world closest to $w$ such that $[\![\Phi]\!]_{c,g^s,w',t} = 1$.
    (b) if $[\![\textit{if}\ \Phi\Psi]\!]_{c,g^s,w,t}$ is defined, then:
    $[\![\textit{if}\ \Phi\Psi]\!]_{c,g^s,w,t} = 1$ if $[\![\Psi]\!]_{c,g^s,w',t} = 1$,where $w'$ is the world closest to $w$ such that $[\![\Phi]\!]_{c,g^s,w',t} = 1$; otherwise $[\![\textit{if}\ \Phi\Psi]\!]_{c,g^s,w,t} = 0$.

14. (a) $[\![B_\tau\varphi]\!]_{M,c,g^s,w,t}$ is defined only if $[\![\varphi]\!]_{M,c,g^s,w',t}$ is defined for every $w' \in \mathcal{W}$ which is a belief world of $[\![\tau]\!]_{M,c,g^s,w,t}$ in $w$.
    (b) if $[\![B_\tau\varphi]\!]_{M,c,g^s,w,t}$ is defined, then:
    $[\![B_\tau\varphi]\!]_{M,c,g^s,w,t} = 1$ if $[\![\varphi]\!]_{M,c,g^s,w',t} = 1$, for every $w' \in \mathcal{W}$ which is a belief world of $[\![\tau]\!]_{M,c,g^s,w,t}$ in $w$;
    $[\![B_\tau\varphi]\!]_{M,c,g^s,w,t} = 0$ if $[\![\varphi]\!]_{M,c,g^s,w',t} = 0$, for some $w' \in \mathcal{W}$ which is a belief world of $[\![\tau]\!]_{M,c,g^s,w,t}$ in $w$.

15. (a) $[\![\textit{believe}(\tau,\varphi)]\!]_{M,c,g^s,w,t}$ is defined only if $[\![\varphi]\!]_{M,c,g^s,w',t}$ is defined, for every $w' \in \mathcal{W}$ which is a belief world of $[\![\tau]\!]_{M,c,g^s,w,t}$ in $w$
    (b) if $[\![\textit{believe}(\tau,\varphi)]\!]_{M,c,g^s,w,t}$ is defined, then:
    $[\![\textit{believe}(\tau,\varphi)]\!]_{M,c,g^s,w,t} = 1$ if $[\![\varphi]\!]_{M,c,g^s,w',t} = 1$, for every $w' \in \mathcal{W}$ which is a belief world of $[\![\tau]\!]_{M,c,g^s,w,t}$ in $w$;
    $[\![\textit{believe}(\tau,\varphi)]\!]_{M,c,g^s,w,t} = 0$ if $[\![\varphi]\!]_{M,c,g^s,w',t} = 0$, for some $w' \in \mathcal{W}$ which is a belief world of $[\![\tau]\!]_{M,c,g^s,w,t}$ in $w$.

16. $[\![E(\tau)]\!]_{M,c,g^s,w,t} = 1$ if $[\![\tau]\!]_{M,c,g^s,w,t} \in \mathcal{I}(w)$; $[\![E(\tau)]\!]_{M,c,g^s,w,t} = 0$ if $[\![\tau]\!]_{M,c,g^s,w,t} \in \overline{\mathcal{I}(w)}$.

**Truth in context**

- $\Phi$ is true in a context $c$, in the model $M$, if $[\![\Phi]\!]_{M,c,c_g^s,c_w,c_t} = 1$
- $\Phi$ is false in a context $c$, in the model $M$, if $[\![\Phi]\!]_{M,c,c_g^s,c_w,c_t} = 0$

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Fabio Del Prete
CLLE-ERSS UMR 5263
Maison de la Recherche
Université de Toulouse Le Mirail
5, allées Antonio Machado
31058 Toulouse Cedex 9
France
fabio.del-prete@univ-tlse2.fr

Sandro Zucchi
Dipartimento di Filosofia
Università degli Studi di Milano
via Festa del Perdono 7
20122 Milano
Italy
alessandro.zucchi@unimi.it