Final submission to *Linguistic Inquiry*, Remarks and Replies,

after full acceptance

The temperature paradox and temporal interpretation*

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September 30, 2007

ABSTRACT: Montague's analysis of the well-known temperature paradox poses a problem for Gupta's syllogism, whose surface syntax differs from the temperature syllogism in the addition of the intensional adverb *necessarily*. Lasersohn (2005) argues that the puzzle arising from these syllogisms can be solved if one adopts the Fregean presuppositional treatment of definite descriptions, and concludes that the temperature-Gupta puzzle provides an argument in favor of such treatment. This paper shows that the analysis of definite descriptions is in fact orthogonal to the puzzle. Instead, it will be shown that the differences between the two syllogisms stem from the temporal interpretation of their premises.

KEYWORDS: Temperature paradox, Gupta's syllogism, intensionality, individual concept, temporal interpretation.

1. The temperature paradox and Gupta's syllogism

One of the triplets that instanciates Partee's well-known temperature paradox is (1)-(3), attributed to Löbner (1981) in Lasersohn (2005):[1]

(1) The temperature in Chicago is (the very same as) the temperature in St. Louis.

(2) The temperature in Chicago is rising.

(3) The temperature in St. Loius is rising.

Intuively, from the truth of (1) and (2), the truth of (3) does not follow.

Montague's (1974) analysis of these sentences is the following. The verb *rise* expresses a property of individual concepts, i.e., a property of functions of type <s,e> from indices (a combination of world and time) to individuals (e.g. degrees on a given scale). For *rise* to be true of one such function $x_{<s,e>}$ at a given index i, we need to compare the value of $x_{<s,e>}$ at i with the value of x at earlier and/or later indices. Equative *be* expresses a two-place property of individual concepts. But, for *be* to be true of $x_{<s,e>}$ and $z_{<s,e>}$ at index i, it suffices that $x_{<s,e>}(i) = z_{<s,e>}(i)$. That is, we do not need to check whether the values of $x_{<s,e>}$ and $z_{<s,e>}$ are identical at earlier/later indices. This is captured in the lexical entry for equative *be* in (4). The analysis assigns to (1)-(3) the translations (5)-(7), which form an invalid syllogism, as desired.[2]

(4) $[\![$*is (the very same as)*$]\!]$ $=$ $\lambda r_{<s,e>} \lambda s_{<s,e>} \lambda i'.\ s(i') = r(i')$

(5) $\lambda i.\ \exists x_{<s,e>} [\ \forall y[\text{temp-Chicago}(y,i) \leftrightarrow x=y] \wedge$

$\exists z_{<s,e>} [\forall v[\text{temp-StLouis}(v,i) \leftrightarrow z=v] \wedge x(i)=z(i)\ ]\ ]$

(6) $\lambda i.\ \exists x_{<s,e>} [\ \forall y[\text{temp-Chicago}(y,i) \leftrightarrow x=y] \wedge \text{rise}(x,i)\ ]$

(7) $\lambda i.\ \exists z_{<s,e>} [\ \forall v[\text{temp-StLouis}(v,i) \leftrightarrow z=v] \wedge \text{rise}(z,i)\ ]$

Note that, in these translations, the formal predicates *temp-Chicago* and *temp-StLouis* are, like their English counterparts *temperature in X*, of type <s,<<s,e>,t>>. Furthermore, to render the syllogism invalid, it is crucial that *be* simply equates the Fahrenheit values of the two temperature functions at i. If, instead, *be* equated the two entire <s,e>-functions, as in (8), (1) would translate as (9) and the syllogism would be valid, contrary to fact.

(8) ⟦*is (the very same as)*⟧ = $\lambda r_{<s,e>}\lambda s_{<s,e>}\lambda i'.\ s = r$

(9) $\lambda i.\ \exists x_{<s,e>}$ [$\forall y$[temp-Chicago(y,i)$\leftrightarrow$x=y] $\wedge$

$\exists z_{<s,e>}$ [$\forall v$[temp-StLouis(v,i)$\leftrightarrow$z=v] $\wedge$ x=z]]

Now consider the syllogism in (10)-(12), based on Anil Gupta's syllogism, cited in Dowty, Wall and Peters (1981:284ff): [3]

(10) Necessarily, the temperature in Chicago is (the very same as) the temperature in St. Louis.

(11) The temperature in Chicago is rising.

(12) The temperature in St. Louis is rising.

Intuitively, this is a valid syllogism: from the truth of (10) and (11), the truth of (12) follows. If we apply Montague's analysis of the sentences (1)-(3) to the sentences here, we obtain the following translations:[4]

(13) $\lambda i.\ \forall i' \in$ Acc(i) [$\exists x_{<s,e>}$ [$\forall y$[temp-Chicago(y,i')$\leftrightarrow$ x=y] $\wedge$

$\exists z_{<s,e>}$ [$\forall v$[temp-StLouis(v,i')$\leftrightarrow$z=v] $\wedge$ x(i')=z(i')]]]

(14) $\lambda i.\ \exists x_{<s,e>}$ [$\forall y$[temp-Chicago(y,i)$\leftrightarrow$ x=y] $\wedge$ rise(x,i)]

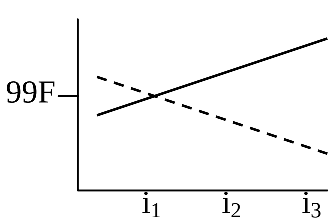
(15) $\lambda i.\ \exists z_{<s,e>}$ [$\forall v$[temp-StLouis(v,i)$\leftrightarrow$z=v] $\wedge$ rise(z,i)]

Gupta notes that, interestingly, these Montague-style translations do not guarantee the validity of the second syllogism: from the truth of the formulas (13) and (14), the truth of (15) does not follow. To see this, consider the model (16) from Dowty, Wall and Peters (1981) and Lasersohn (2005), in which there are three indices temporally ordered ($i_1 < i_2 < i_3$) and the three indices stand to all three indices in the accessibility relation encoded by *necessarily*. Recall that, in Montague, *the temperature in Chicago* denotes, at a given index (or, more intuitively, in a given world), a function from indices (more intuitively, times) to temperature values. For example, *the temperature in Chicago* denotes at index i_1 the <s,e>-function C_1 (solid line in the leftmost diagram), and *the temperature in St. Louis* denotes at i_1 the <s,e>-function L_1 (dotted line), and so on.

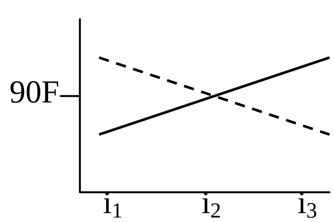
(16)

⟦*temp-Chicago*⟧$(i_1)=\{C_1\}$	⟦*temp-Chicago*⟧$(i_2)=\{C_2\}$	⟦*temp-Ch.*⟧$(i_3)=\{C_3\}$
with $C_1(i_1) = 99$	with $C_2(i_1) = 89$	with $C_3(i_1) = 79$
$C_1(i_2) = 100$	$C_2(i_2) = 90$	$C_3(i_2) = 80$
$C_1(i_3) = 101$	$C_2(i_3) = 91$	$C_3(i_3) = 81$
⟦*temp-StLouis*⟧$(i_1)=\{L_1\}$	⟦*temp-StLouis*⟧$(i_2)=\{L_2\}$	⟦*temp-StL.*⟧$(i_3)=\{L_3\}$
with $L_1(i_1) = 99$	with $L_2(i_1) = 91$	with $L_3(i_1) = 83$
$L_1(i_2) = 98$	$L_2(i_2) = 90$	$L_3(i_2) = 82$
$L_1(i_3) = 97$	$L_2(i_3) = 89$	$L_3(i_3) = 81$

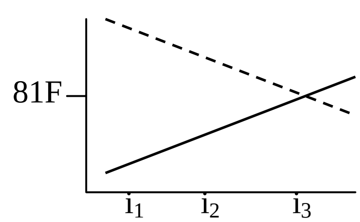
C_1 and L_1



C_2 and L_2



C_3 and L_3



In this model, (13) is true at index i_1, since at all indices i' accessible from i_1 the formula $\exists x_{<s,e>}[\forall y[\text{temp-Chicago}(y,i')\leftrightarrow x=y] \wedge \exists z_{<s,e>}[\forall v[\text{temp-StLouis}(v,i')\leftrightarrow z=v] \wedge x(i')=z(i')]]]$ is true: the unique $x_{<s,e>}$ for which $\forall y[\text{temp-Chicago}(y,i_1)\leftrightarrow x=y]$ is true and the unique $z_{<s,e>}$ for which $[\forall v[\text{temp-StLouis}(v,i_1)\leftrightarrow z=v]$ is true are such that $x(i_1)=z(i_1)$ (since they both equal 99); the unique $x_{<s,e>}$ for which $\forall y[\text{temp-Chicago}(y,i_2)\leftrightarrow x=y]$ is true and the unique $z_{<s,e>}$ for which $[\forall v[\text{temp-StLouis}(v,i_2)\leftrightarrow z=v]$ is true are such that $x(i_2)=z(i_2)$ (since they both equal 90); and the unique $x_{<s,e>}$ for which $\forall y[\text{temp-Chicago}(y,i_3)\leftrightarrow x=y]$ is true and the unique $z_{<s,e>}$ for which $[\forall v[\text{temp-StLouis}(v,i_3)\leftrightarrow z=v]$ is true are such that $x(i_3)=z(i_3)$ (since they both equal 81). The formula (14) is also true in this model when evaluated at i_1, since the unique $x_{<s,e>}$ for which $\forall y[\text{temp-Chicago}(y,i_1)\leftrightarrow x=y]$ is true –namely, C_1– is a rising function. But the conclusion (15) is false at i_1, since the unique $z_{<s,e>}$ for which $\forall y[\text{temp-St Louis}(y,i_1)\leftrightarrow x=y]$ is true –namely, L_1– is not a rising, but a falling function.[5]

Hence, the puzzle. Löbner's version of Partee's syllogism has the same surface syntax as our version of Gupta's syllogism, except for the fact that the latter has an added *necessarily* in the first premise. The first syllogism is invalid and, to ensure its invalidity, we need *be* to equate values –as in (4)– and not <s,e>-functions –as in (8). The second syllogism is valid, but, if we translate it as we translated the previous one with the sole addition of the meaning of *necessarily*, we wrongly predict the second syllogism to be invalid. To yield the correct result for the second syllogism, we would need to treat *be* not as equating values, but as equating functions with the outcome in (17) (or we would need something else leading to similar truth conditions).

(17) $\lambda i.\ \forall i' \in Acc(i)\ [\ \exists x_{<s,e>}\ [\ \forall y[temp(y,i') \leftrightarrow x=y]\ \wedge$

$$\exists z_{<s,e>}\ [\ \forall v[price(v,i') \leftrightarrow z=v]\ \wedge\ x=z\ ]\ ]\ ]$$

2. Lasersohn's (2005) proposal and its limitations

2.1. Lasersohn's proposal

Lasersohn (2005) proposes a solution to this puzzle based on the treatment of definite descriptions. In a nutshell, he notes that the Russellian treatment of definite NPs requires a higher type for the N' that leads to models like (16); he then argues that the Fregean treatment allows for a lower type of the N' that avoids models like (16).

Let us see Lasersohn's argument in more detail. According to him, the problem with the Montague-style translations above is that they presume that the English noun *temperature* (or the N' *temperature in NP*) expresses a property of individual concepts (type <s,<<s,e>,t>>) rather than a simple property of individuals (type <s,<e,t>>), thus allowing for models like (16). Under the Russellian treatment of definite descriptions, one is forced to assume the higher type <s,<<s,e>,t>>. The meaning of the verb *rise* applies to <s,e>-functions. Hence, the formula $rise(x_{<s,e>},w)$ in (6)/(14) must contain an individual concept term –here, $x_{<s,e>}$– as argument. Since x is equated with y in (6)/(14) under the Russellian treatment of definite descriptions, we must have the individual concept term $y_{<s,e>}$ in the formula $temp\text{-}Chicago(y_{<s,e>},w)$ as well. Thus, the meaning of the English N' *temperature of Chicago* must apply to <s,e>-functions, not to individuals. (The same reasoning holds for the N' *temperature in St. Louis*.).

Then, Lasersohn notes that, if one assumes instead a Fregean approach to definite descriptions, we can maintain that the meaning of the verb *rise* applies to individual concepts while having a lower type <s,<e,t>> for the N' *temperature in NP*: we simply take the Fregean intension of the definite description *the temperature in NP* –type <s,e>–, and plug it as argument of *rise*. (This could not be done for the Russellian treatment, as the type of the Russellian intension –<<<s,e>,<s,t>>, <s,t>>– would not fit into the <s,e>-argument slot of *rise*.) The result is (18)-(21).[6] Note, furthermore, that this analysis keeps a uniform treatment of *be* as equating temperature values –as in (4)– for the two sentences (1) and (10).

(18) $\lambda i.\ \iota x_e\ [\text{temp-Chicago}(x,i)] \ = \ \iota z_e\ [\text{temp-StLouis}(z,i)]$

(19) $\lambda i.\ \text{rise}\ (\ \lambda i'.\iota x_e[\text{temp-Chicago}(x,i')],\ i\ )$

(20) $\lambda i.\ \text{rise}\ (\ \lambda i'.\iota z_e[\text{price-StLouis}(z,i')],\ i\ )$

(21) $\lambda i.\ \forall i' \in \text{Acc}(i)\ \ [\ \iota x_e\ [\text{temp-Chicago}(x,i')] \ = \ \iota z_e\ [\text{temp-StLouis}(z,i')]\ ]$

Lasersohn concludes that the temperature-Gupta puzzle supports the Fregean treatment of definite descriptions.

2.2. Limitations of Lasersohn's proposal

Although Lasersohn's proposal derives the desired results for the examples considered so far, it does not solve the problem. The same puzzle can be reconstructed using a variant of Partee's invalid syllogism and a variant of Gupta's valid syllogism for which Lasersohn's solution cannot be used.

To see this, consider the variant of the first syllogism in (22)-(24). As before, the syllogism is invalid. Consider also the variant of Gupta's syllogism in (25), (23) and (24), whose surface syntax differs from that of the first one only in the presence of *necessarily*. As before, this second syllogism is intuitively valid.

(22) The prices in supermarket A are (the very same as) the prices in supermarket B.

(23) One / three / most price(s) in supermarket A is (/are) rising.

(24) One / three / most price(s) in supermarket B is (/are) rising.

(25) Necessarily, the prices in supermarket A are (the very same as) the prices in supermarket B.

We have the same puzzle as before, but now the subject of *rise* in the second premise and in the conclusion is not a definite description, but a quantificational NP. We have to quantify over an object x of which both the restrictor property expressed by the N' *price in supermarket X* and the nuclear scope property expressed by *rise* are predicated. Since *rise* is a predicate of individual concepts, that object x has to be of type <s,e>. Thus, we are back to the Montague-style translations, having the N' *price(s) in supermaket X* as type <s,<<s,e>,t>> and using the formula *price-in-X*$(y_{<s,e>},w)$ as its translation throughout the sentences. Regarless of whether we treat the plural definite NPs in (22) and (25) à la Russell or à la Frege, a unified analysis of the two syllogisms – in particular, a unified analysis with equative *be* as in (4)– leads to the same puzzle as before. It correctly derives the invalidity of the first syllogism, as seen in the translations (26)-(28). But it fails to ensure the validity of the second syllogism, since the translations

(29), (27) and (28) allow for falsifying models like (30) (with $i_1 < i_2 < i_3$ and with the three indices accessible from all three indices).[7]

(26) $\lambda i.\ [\ \sigma x_{<s,e>}[\text{price-in-A*}(x,i)]\ (i)\ =\ \sigma z_{<s,e>}[\text{price-in-B*}(v,i)]\ (i)\ ]$

(27) $\lambda i.\ \exists x_{<s,e>}\ [\ \text{price-in-A}(x,i)\ \wedge \text{rise}(x,i)\ ]$

(28) $\lambda i.\ \exists z_{<s,e>}\ [\ \text{price-in-B}(v,i) \wedge \text{rise}(z,i)\ ]$

(29) $\lambda i.\ \forall i' \in \text{Acc}(i)\ [\ \sigma x_{<s,e>}[\text{price-in-A*}(x,i')]\ (i')\ =\ \sigma z_{<s,e>}[\text{price-in-B*}(v,i')]\ (i')\ ]$

(30)

$[\![\textit{price-A}]\!](i_1)=\{A_{11},A_{12}\}$		$[\![\textit{price-A}]\!](i_2)=\{A_{21},A_{22}\}$		$[\![\textit{pr.-A}]\!](i_3)=\{A_{31},A_{32}\}$	
with	$A_{11}(i_1) = 99$	with	$A_{21}(i_1) = 89$	with	$A_{31}(i_1) = 79$
	$A_{11}(i_2) = 100$		$A_{21}(i_2) = 90$		$A_{31}(i_2) = 80$
	$A_{11}(i_3) = 101$		$A_{21}(i_3) = 91$		$A_{31}(i_3) = 81$
with	$A_{12}(i_1) = 29$	with	$A_{22}(i_1) = 19$	with	$A_{32}(i_1) = 9$
	$A_{12}(i_2) = 30$		$A_{22}(i_2) = 20$		$A_{32}(i_2) = 10$
	$A_{12}(i_3) = 31$		$A_{22}(i_3) = 21$		$A_{32}(i_3) = 11$
$[\![\textit{price-B}]\!](i_1)=\{B_{11},B_{12}\}$		$[\![\textit{price-B}]\!](i_2)=\{B_{21},B_{22}\}$		$[\![\textit{pr.-B}]\!](i_3)=\{B_{31},B_{32}\}$	
with	$B_{11}(i_1) = 99$	with	$B_{21}(i_1) = 91$	with	$B_{31}(i_1) = 83$
	$B_{11}(i_2) = 98$		$B_{21}(i_2) = 90$		$B_{31}(i_2) = 82$
	$B_{11}(i_3) = 97$		$B_{21}(i_3) = 89$		$B_{31}(i_3) = 81$
with	$B_{12}(i_1) = 29$	with	$B_{22}(i_1) = 21$	with	$B_{32}(i_1) = 13$
	$B_{12}(i_2) = 28$		$B_{22}(i_2) = 20$		$B_{32}(i_2) = 12$
	$B_{12}(i_3) = 27$		$B_{22}(i_3) = 19$		$B_{32}(i_3) = 11$

A reviewer points out that nouns like *price* inherently express a relation between two individuals –a degree and a product–, and that, in fact, sentence (23) *One / three / most prices in supermarket A are rising* has the same meaning as sentence (31), where the product argument is explicit. If one syntactically rewrites sentences like (23) as in (31), one could apply Lasersohn's solution to these cases and maintain the simpler type <s,<(e,)<e,t>>> for the N' *price in supermarket A.*

(31) The price(s) of one product / three products / most products in supermarket A are rising.

Here, I want to point out that using this rewriting to make Lasersohn's analysis applicable to the quantificational variants would yield unwelcome results for the rest of the grammar. To see this, consider example (32) and its readings A and B (Heim 1979, Romero 2005):

(32) John knows the price in supermarket S that Fred knows.

a. Reading A: "John knows the same price in supermarket S as Fred does."

b. Reading B: "John knows what price in supermarket S Fred knows."

Under reading A, the sentence means that John and Fred know the same price in supermarket S, e.g., they both know how much the milk costs in S. Under reading B, John knows what price Fred knows, e.g. John knows that Fred knows how much the milk costs in supermarket S. But, crucially, John may not know himself how much the milk costs.[8]

Now, consider what readings we would obtain if we maintained Lasersohn's lower type <s,<(e,)<e,t>>> for *price* and sentence (32) was syntactically rewritten as in (33). The closest that we can get to the desired ambiguity is by varying the world evaluation of the NP *[the product y_e (in supermarket S) such that Fred knows the price of y_e]*: it can be treated as transparent (de re) or as opaque (de dicto) with respect to the matrix *know*:

(33) John knows the price of [$_{NP}$ the product y_e (in supermarket S) such that Fred knows the price of y_e].

a. NP transparent: "Consider the unique product y_e such that Fred knows how much y_e costs. John knows how much y_e costs too." = Reading A

b. NP opaque: "Consider each product y_e that John thinks might be the product whose price Fred knows (that is, each product y_e for which there is some doxastic/epistemic alternative w' of John's where y_e is the product whose price Fred knows in w'). For each such y_e, John assigns to y_e at the corresponding w' the correct, actual-world dollar amount."[9] ≠ Reading B

While the transparent treatment in (33a) yields the same truth conditions as reading A, the opaque treatment does not correspond to any reading of the original sentence. According to reading B, John knows exactly what price Fred knows, but (33b) does not guarantee this full knowledge. Furthermore, according to (33b), for the products y_e John is considering, John may assign them the correct dollar amount only in some of his doxastic worlds, that is, he may not be sure about their dollar price. This is not reading A either, which required full knowledge of the actual dollar amount. In sum, (33b) does not correspond to any reading of the original sentence (32).

In conclusion, this type of rewriting combined with the lower semantic type <s,(<e,)<e,t>>> does not generally preserve truth-conditions. Introducing this in the grammar is a dangerous move: it would allow us to reduce the quantificational variants (22)-(25) to Lasersohn's analysis, but at the expense of not deriving correct readings and generating incorrect ones. Without this rewriting, (22)-(25) bring us back to Montague's analysis and to the original puzzle: Montague's analysis correctly makes the temperature paradox invalid, but it fails to derive the intuitive validity of Gupta's syllogism.

In the next section, I show that, once we look at the complete empirical pattern of the two syllogisms, no puzzle arises. Treating the N' *temperature* and *price* as type <s,<<s,e>,t>> –as in Montague– and using no rewriting derives in fact the right results. This is so regardless of whether we use a Russellian or a Fregean treatment of definite descriptions.

3. New proposal

I will argue that the temperature paradox and Gupta's syllogism behave differently intuitively because of the temporal interpretation of their premises (1) and (10). In their current form, the two syllogisms do not constitute a minimal pair. When a truly minimal pair is compared, the two syllogisms behave intuitively alike and no puzzle arises.

To see this, consider first the simple examples (31)-(32). Present tense can give rise to an episodic “now” reading, as with statives like (31), or to a habitual reading with a hidden operator GEN(eric) or “always”, as in (32).

(31) a. John is upset.

b. Necessarily, John is upset.

(32) a. John eats cereal for breakfast.

b. Necessarily, John eats cereal for breakfast.

In a similar way, the copular sentence (1) has in principle two readings. When interpreted episodically as an assertion about the facts right now –as originally intended–, the syllogism is invalid.[10] But, interestingly, if we manage to construe a habitual interpretation for (1) –as in example (33)–, the syllogism becomes valid.

(33) Since the two cities have extremely similar geothermic conditions, the temperature in Barcelona is (always the very same as) the temperature in LA.

Something similar happens with (10). The most salient –and intended– interpretation of the clause embedded under *necessarily* is as a temporally habitual statement. Under this interpretation, the syllogism is valid. But if we manage to interpret this clause as episodic, as in (34), the syllogism is invalid.

(34) Superman was ordered to make all the cities in the MidWest have today 80F. Since Superman never disobeys an order, necessarily the temperature in Chicago is (today the very same as) the temperature in St. Louis.

This means that Gupta's syllogism differs from Partee's syllogism not just in the addition of *necessarily*, but also in the presence of a hidden operator "always" or a hidden operator "now". The proposed translations are (35)-(38), with the translated English sentence indicated in square brackets. Note that the formula (35b) is the same as the originally problematic formula (13), but, crucially, now (35b)/(13) is the translation of example (34), not of example (10).

(35) Translations under the episodic "now" reading:

a. $\lambda i.\ \exists x_{<s,e>}$ [$\forall y$[temp-Chicago(y,i)$\leftrightarrow$ x=y] $\wedge$ [translation for (1)]

$\exists z_{<s,e>}$ [$\forall v$[temp-StLouis(v,i)$\leftrightarrow$z=v] $\wedge$ x(i)=z(i)]]

b. $\lambda i.\ \forall i' \in$ Acc(i) [$\exists x_{<s,e>}$ [$\forall y$[temp-Chicago(y,i')$\leftrightarrow$ x=y] $\wedge$ [for (34)]

$\exists z_{<s,e>}$ [$\forall v$[temp-StLouis(v,i')$\leftrightarrow$z=v] $\wedge$ x(i')=z(i')]]]

(36) $\lambda i.\ \exists x_{<s,e>}$ [$\forall y$[temp-Chicago(y,i)$\leftrightarrow$ x=y] $\wedge$ rise(i)] [for (2)/(11)]

(37) $\lambda i.\ \exists z_{<s,e>}$ [$\forall v$[temp-StLouis(v,i)$\leftrightarrow$z=v] $\wedge$ rise(z,i)] [for (3)/(12)]

(38) Translations under the habitual "always" reading:

a. $\lambda i.\ \exists x_{<s,e>}$ [$\forall y$[temp-Barcelona(y,i)$\leftrightarrow$ x=y] $\wedge$ [for (33)]

$\exists z_{<s,e>}$ [$\forall v$[temp-LA(v,i)$\leftrightarrow$z=v] $\wedge$ $\forall i'' \leq i$[x(i'')=z(i'')]]]

b. $\lambda i.\ \forall i' \in$ Acc(i) [$\exists x_{<s,e>}$ [$\forall y$[temp-Chicago(y,i')$\leftrightarrow$ x=y] $\wedge$ [for (10)]

$\exists z_{<s,e>}$ [$\forall v$[temp-StLouis(v,i')$\leftrightarrow$z=v] $\wedge$ $\forall i'' \leq i'$[x(i'')=z(i'')]]]]

To get to these translations, different argument slots of type s in the <s,<<s,e>,t>> intension of the N' are filled with arguments provided by different operators in the sentence. The first s argument in the $<\underline{s},<<s,e>,t>>$-function is bound by *necessarily* or remains unfilled as the top λi. The s argument of the individual concept argument in the $<s,<<\underline{s},e>,t>>$-function is bound by “always” or by “now”.[11] It is this second, temporal operator layer that is responsible for the (in)validity of the syllogism. Under the episodic “now” interpretation, the translation of the first premise –(35a,b)– only guarantees that the individual concepts $x_{<s,e>}$ and $z_{<s,e>}$ yield the same temperature value at the corresponding speech index (or at a counterpart of it). From that and from $x_{<s,e>}$ being a rising function, it does not follow that $z_{<s,e>}$ will be one too. Thus, the syllogism is invalid, with –(35b)-(36)-(37)– or without *necessarily* –(35a)-(36)-(37). Under the habitual interpretation, the hidden quantifier “always” ensures that the two individual concepts $x_{<s,e>}$ and $z_{<s,e>}$ will yield identical values at all indices part (≤) of the relevant index. From that and from the fact that $x_{<s,e>}$ is a rising function at that relevant index, it follows that $z_{<s,e>}$ is a rising function in that index too. Thus, the syllogism is valid, with –(38b)-(36)-(37)– or without *necessarily* –(38a)-(36)-(37).

We have seen that the intuitive (in)validity judgements for Partee’s and Gupta’s syllogisms follow if we assume that different binders in the sentence bind different s slots in the $<s,<<s,e>,t>>$ function, with the temporal binder playing the crucial role. But a question remains: Does our grammar also allow for a semantic derivation in which the two s slots are bound by the same quantifier, e.g. *necessarily* in (10) or *always* in (39)?

(39) Always, the temperature in Barcelona is (the very same) as the temperature in LA.

Let us assume, for the sake of the argument, that the answer is ‘yes’.[12] In the case of *necessarily*, a semantic computation where the adverb binds both s slots would output the truth conditions in (13), which coincide with the eventive "now" reading in (35b). This means that, even if the grammar allowed for a syntactic configuration with no (active) temporal operator under *necessarily*, the resulting reading would feel like the eventive "now" reading we get for (34). Thus, the syllogism would be judged invalid, and its formal translation would correctly render it invalid.

In the case of *always*, a semantic derivation for (39) in which both situation arguments are bound by *always* would yield the translation in (40):

(40) $$\lambda i.\ \forall i'' \leq i\ [\ \exists x_{<s,e>}\ [\ \forall y[\text{temp-Barcelona}(y,i'') \leftrightarrow x=y]\ \wedge$$
$$\exists z_{<s,e>}\ [\forall v[\text{temp-LA}(v,i'') \leftrightarrow z=v]\ \wedge\ x(i'')=z(i'')\ ]\ ]\ ]$$

But (40) (roughly) encodes the same truth conditions as the formula (38a).[13] This means that, if the grammar allowed for a syntactic configuration where *always* binds both situation arguments, the resulting reading would be confounded with the plain habitual reading where *always* only binds over *be* (where it only binds the second situation in the $<s,<<\underline{s},e>,t>>$-function). Hence, the syllogism would be judged valid –as it would with (33)– and its formal translations would correctly derive its validity.

4. Conclusion

Contra Lasersohn (2005), the treatment of definite descriptions is orthogonal to the puzzle posed by the temperature paradox and Gupta's syllogism. The essence of the puzzle remains untouched in examples where a noun like *temperature* or *price* appears headed by a quantificational determiner and where Lasersohn's solution cannot be applied. The key to the puzzle lies, instead, in the temporal interpretation of the first premise. Once we control for its temporal interpretation and form truly minimal pairs between the temperature and Gupta's syllogisms, the two syllogisms behave alike and the puzzle does not arise. An eventive "now" interpretation of the main predication in the first premise –without *necessarily*, as in the temperature paradox, or with *necessarily*– makes the syllogism invalid, since it only guarantees that the two temperature values are equal at a given index. A habitual interpretation of the main predication –with *necessarily*, as in Gupta's syllogism, or without *necessarily*– makes the syllogism valid, since it ensures that the two temperature values are equal at all indices part of the relevant index.

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Endnotes

* I thank the audiences of Sinn und Bedeutung 11, the University of Massachusetts, the University of Konstanz, UCLA and the University of Tübingen for helpful comments. Special thanks to two anonymous reviewers and to Rajesh Bhatt, Veneeta Dayal, Kai von Fintel, Lance Nathan, Uli Sauerland, Magdalena Schwager, Wolfgand Spohn and Arnim von Stechow for their valuable insights. Remaining errors are mine.

[1] The original sentences from Barbara H. Partee are (i)-(iii). The (apparent) paradox is that, despite the equation in (i), the truth of the predication in (ii) does not guarantee the truth of the predication in (iii).

(i) The temperature is ninety.

(ii) The temperature rises.

(iii) Ninety rises.

[2] The translations proposed in previous literature are replicated throughout this paper using a formal Ty2 language with explicit quantification over indices. The lexical entry in (4) has been modified from Montague's original entry to better match current assumptions about the syntax-semantics interface (see Heim and Kratzer 1998). For the sake of illustration –and maintaining Montague's Russellian treatment of definite descriptions–, the syntax and semantic computation of sentence (1) leading to (5) is in (i)-(ii).

(i) The temperature in Chicago 1 [the temperature in St. Louis 2 [t_1 is t_2]]

(ii) a. $[\![t_1 \text{ is } t_2]\!] = \lambda i'.\ g(1)(i') = g(2)(i')$

b. $[\![2\ [t_1 \text{ is } t_2]]\!] = \lambda z_{<s,e>} \lambda i'.\ g(1)(i') = z(i')$

c. $[\![\textit{temperature in NP}]\!] = \lambda i^*.\lambda v_{<s,e>}.\ \text{temp-NP}(v,i^*)$ (type $\underline{<s,<<s,e>,t>>}$)

d. $[\![\textit{the}]\!] = \lambda P_{<s,<<s,e>,t>>}.\lambda Q_{<<s,e>,<s,t>>}.\lambda i.\ \exists z_{<s,e>} [\ \forall v[P(i)(v) \leftrightarrow z=v] \wedge Q(z)(i)\ ]$

e. $[\![\textit{the temperature in St. Louis}]\!] =$

$\lambda Q_{<<s,e>,<s,t>>} \lambda i.\ \exists z_{<s,e>} [\forall v[\text{temp-StLouis}(v,i) \leftrightarrow z=v] \wedge Q(z)(i)]$

f. ⟦ *the temperature in St. Louis 2 [t_1 is t_2]* ⟧ =

$\lambda i.\ \exists z_{<s,e>}$ [$\forall v$[temp-StLouis(v,i)$\leftrightarrow$z=v] $\wedge$ g(1)(i)=z(i)]

g. ⟦ *1 [the temperature in St. Louis 2 [t_1 is t_2]]* ⟧ =

$\lambda x_{<s,e>}\lambda i.\ \exists z_{<s,e>}$ [$\forall v$[temp-StLouis(v,i)$\leftrightarrow$z=v] $\wedge$ x(i)=z(i)]

h. ⟦*The temperature in Chicago*⟧ =

$\lambda Q_{<<s,e>,<s,t>>}\lambda i.\ \exists x_{<s,e>}$ [$\forall y$[temp-Chicago(y,i)$\leftrightarrow$x=y] $\wedge$ Q(x)(i)]

i. ⟦ *The temperature in Chicago 1 [the temperature in St. Louis 2 [t_1 is t_2]]* ⟧ =

$\lambda i.\ \exists x_{<s,e>}$ [$\forall y$[temp-Chicago(y,i)$\leftrightarrow$x=y] $\wedge$

$\exists z_{<s,e>}$ [$\forall v$[temp-StLouis(v,i)$\leftrightarrow$z=v] $\wedge$ x(i)=z(i)]]

[3] Gupta's original syllogism is (i)-(iii). Following Nathan (2005), (i) can be understood as the elliptical version of e.g. *Necessarily, the temperature in degrees Fahrenheit is the price in cents of a can of Coke*. The sentences chosen in the text illustrate the same (type of) valid syllogism and make the contrast between this and Partee's syllogism more apparent.

(i) Necessarily, the temperature is the price.

(ii) The temperature is rising.

(iii) The price is rising.

[4] The formula in (13) is the result of combining the meaning of *necessarily* in (i) with the formula in (5):

(i) ⟦ *necessarily* ⟧ = $\lambda P_{<s,t>}\lambda i.\ \forall i' \in Acc(i)\ [P(i')]$

[5] One might argue that (16) is an *im*possible model –and thus irrelevant– on the following

grounds. No matter what functions C_m and C_n we choose as possible extensions of the N' *temperature of Chicago*, C_m and C_n have to be consistent with each other, in that they have to map each index shared by their domains to the same temperature value. Otherwise, at a particular time-world coordinate i_{10}, Chicago would have two different temperature values. (See related discussion in e.g. Putnam (1975).) I will not explore this objection in this paper, but follow Dowty, Wall and Peters (1981) and Lasersohn (2005) in presuming that the model (16) is acceptable. The analysis to be proposed here will circumvent the problem by showing that, in fact, Gupta's syllogism is intuitively invalid in some contexts, and that this is correctly predicted by the existence of (16) itself or models similar to it.

[6] Sentences (1) and (10) have the syntax and semantic derivation in (i)-(ii) in Lasersohn's proposal:

(i) (Necessarily) [The temperature in Chicago [is (the very same as) the temperature in St. Louis]]

(ii) a. ⟦*temperature in NP*⟧ = $\lambda i^*.\lambda v_e.$ temp-NP(v,i*) (type <u><s,<e,t>></u>)

b. ⟦*the temperature in St. Louis*⟧ = $\lambda i^*.\iota z_e$[temp-StLouis(z,i*)]

(=<u>Intension of NP: <s,e></u>)

c. ⟦*is (the very same as) the temperature in St. Louis*⟧ =

$\lambda s_{<s,e>}\lambda i'.\ s(i') = \iota z_e$[temp-StLouis(z,i')]

d. ⟦*The temperature in Chicago*⟧ = $\lambda i^*.\iota x_e$[temp-Chicago(x,i*)]

(=<u>Intension of NP: <s,e></u>)

e. ⟦*The temperature in Chicago is (the very same as) the temperature in St. Louis*⟧ =

$\lambda i'.\ \iota x_e[\text{temp-Chicago}(x,i')] = \iota x_e[\text{temp-StLouis}(x,i')]$

f. ⟦*necessarily*⟧ = $\lambda P_{<s,t>}\lambda i.\ \forall i' \in Acc(i)\ [P(i')]$

g. ⟦*Necessarily [the temperature in Chicago is (the very same as) the temperature in St. Louis]*⟧ =

$\lambda i.\ \forall i' \in Acc(i)\ [\ \iota x_e\ [\text{temp-Chicago}(x,i')] = \iota z_e\ [\text{temp-StLouis}(z,i')]\ ]$

[7] (26) and (29) assume that plural sums can be formed not just of individuals, but also of objects of higher type, in this case, of <s,e>-functions. Functional application of a plural sum of functions $\beta_1 \cup \beta_2 \ldots \cup \beta_n$ to an argument α can be performed following Gawron and Kehler's (2004) Boolean Reduction in (i). Alternatively, we could exploit the fact the sentences (22) and (25) seem to have a hidden modifier *corresponding(ly)* or *respective(ly)*. In this case, we could translate e.g. (22) as (ii), where f is a sequencing function that applies to a plural sum to yield a function from natural numbers to atomic parts of that sum, exhausting the sum. See Gawron and Kehler (2004) for further details on the analysis of *respectively*.

(i) Boolean Reduction: For each type <a,b>, we require of the part-of relation ordering the $\cup$-semilattice that:

$\forall \alpha \in D_a, \forall \beta_1,\beta_2 \ldots \beta_n \in D_{<a,b>}\ [\ [\beta_1 \cup \beta_2 \ldots \cup \beta_n](\alpha) = \beta_1(\alpha) \cup \beta_2(\alpha) \ldots \beta_n(\alpha)\ ]$

(ii) $\lambda i.\ \bigcup_{1 \leq n \leq |f|} [f(\sigma x_{<s,e>}\ [\text{price-in-A*}(x,i)])(n)(i) = f(\sigma z_{<s,e>}\ [\text{price-in-B*}(v,i)])(n)(i)]$

[8] The formal translations for readings A and B are (iii) and (iv) respectively (Romero

2005), differing on whether matrix *know* takes the <s,e>-extension or the <s,<s,e>>-intension of the NP *the price in supermarket S that Fred knows*. Note that the N' *price in supermarket S* and the corresponding formal predicate are of the higher type <s,<<s,e>,t>>, as in (i)-(ii). $Dox_f(w^*)$ stands for the set of worlds that conform to Fred's beliefs in w*.

(i) $[\![$*price in supermarket S*$]\!]$ $= \quad \lambda x_{<s,e>}\lambda w^*.\ \text{price-in-A}(x,w^*)$

(ii) $[\![$*the price in supermarket S that Fred knows*$]\!]$ $=$

$$\lambda w^*.\ \iota x_{<s,e>}\ [\ \text{price-in-S}(x,w^*)\ \&\ \forall w'' \in Dox_f(w^*)\ [x(w'') = x(w^*)]\ ]$$

(=Intension of the NP)

(iii) Reading A: *Know* + extension of the NP in the actual world w

$$\lambda w. \forall w' \in Dox_j(w)\ [\ \iota x_{<s,e>}[\text{price-in-S}(x,w)\ \&\ \forall w'' \in Dox_f(w)[x(w'') = x(w)]]\ (w') =$$
$$\iota x_{<s,e>}\ [\text{price-in-S}(x,w)\ \&\ \forall w'' \in Dox_f(w)[x(w'') = x(w)]]\ (w)\quad]$$

(iv) Reading B: *Know* + intension of the NP

$$\lambda w.\ \forall w' \in Dox_j(w)$$
$$[\ \lambda w^*.\ \iota x_{<s,e>}\ [\text{price-in-S}(x,w^*)\ \&\ \forall w'' \in Dox_f(w^*)[x(w'') = x(w^*)]]\ \ (w') =$$
$$\lambda w^*.\ \iota x_{<s,e>}\ [\text{price-in-S}(x,w^*)\ \&\ \forall w'' \in Dox_f(w^*)[x(w'') = x(w^*)]]\ \ (w)\quad]$$

which simplifies as

$$\lambda w.\ \forall w' \in Dox_j(w)\ [\ \iota x_{<s,e>}\ [\text{price-in-S}(\underline{x},w')\ \&\ \forall w'' \in Dox_f(w')[x(w'') = x(w')]] =$$
$$\iota x_{<s,e>}\ \ [\text{price-in-S}(x,w)\ \&\ \forall w'' \in Dox_f(w)[x(w'') = x(w)]]\quad]$$

[9] The formulas for readings (33a) and (33b) are (i) and (ii) respectively, differing solely in the evaluation world for the NP *the product that Fred knows the price of*. The N' *price*

in supermarket S and the corresponding formal predicate are of the lower type <s,<e,<e,t>>>.

(i) Transparent reading: "the product that Fred knows the price of in the actual world w."

$$\lambda w.\ \forall w' \in Dox_j(w)$$

$$[\ \iota x_e\ [\text{price-of-in-S}\ (x,\ \iota y_e[\text{product}(y,\mathbf{w})\ \&\ \forall w'' \in Dox_f(\mathbf{w})[\iota z_e[\text{price-of-in-S}(z,y,w'')] = \iota z_e[\text{price-of-in-S}(z,y,\mathbf{w})]]],\ w')] =$$

$$\iota x_e\ [\text{price-of-in-S}\ (x,\ \iota y_e[\text{product}(y,\mathbf{w})\ \&\ \forall w'' \in Dox_f(\mathbf{w})[\iota z_e[\text{price-of-in-S}(z,y,w'')] = \iota z_e[\text{price-of-in-S}(z,y,\mathbf{w})]]],\ w)]\ ]$$

(ii) Opaque reading: For each belief world w' of John's, "the product that Fred knows the price of in w' ".

$$\lambda w.\ \forall w' \in Dox_j(w)$$

$$[\ \iota x_e\ [\text{price-of-in-S}\ (x,\ \iota y_e[\text{product}(y,\mathbf{w'})\ \&\ \forall w'' \in Dox_f(\mathbf{w'})[\iota z_e[\text{price-of-in-S}(z,y,w'')] = \iota z_e[\text{price-of-in-S}(z,y,\mathbf{w'})]]],\ w')] =$$

$$\iota x_e\ [\text{price-of-in-S}\ (x,\ \iota y_e[\text{product}(y,\mathbf{w'})\ \&\ \forall w'' \in Dox_f(\mathbf{w'})[\iota z_e[\text{price-of-in-S}(z,y,w'')] = \iota z_e[\text{price-of-in-S}(z,y,\mathbf{w'})]]],\ w)]\ ]$$

[10] This episodic "now" interpretation is the intended reading in Löbner's syllogism, since the sentence was construed as a variant to Partee's sentence *The temperature is ninety*. See footnote 1.

[11] For the purposes of this paper, the operator lexical entries (ii)-(iii) will suffice. The syntax and semantic computation of sentence (10) leading to (38b) is (iv)-(v):

(i) ⟦ *necessarily* ⟧ = $\lambda P_{<s,t>}\lambda i.\ \forall i' \in Acc(i)\ [P(i')]$

(ii) ⟦ *always* ⟧ = $\lambda P_{<s,t>}\lambda i.\ \forall i'' \leq i\ [P(i'')]$

(iii) ⟦ *now* ⟧ = $\lambda P_{<s,t>}\lambda i.\ P(i)$

(iv) Necessarily [the temperature in Chicago 1 [the temperature in St. Louis 2 [always [t_1 is t_2]]]]

(v) a. ⟦ *t_1 is t_2* ⟧ = $\lambda i'.\ g(1)(i') = g(2)(i')$

b. ⟦ *always t_1 is t_2* ⟧ = $\lambda i.\ \forall i'' \leq i\ [g(1)(i'') = g(2)(i'')]$

c. ⟦ *the temperature in St. Louis 2 [always t_1 is t_2]* ⟧ =

$\lambda i.\ \exists z_{<s,e>}\ [\ \forall v[\text{temp-StLouis}(v,i) \leftrightarrow z=v]\ \wedge\ \forall i'' \leq i\ [g(1)(i'') = z(i'')]\ ]$

d. ⟦ *The temperature in Chicago 1 [the temperature in St. Louis 2 [always t_1 is t_2]]* ⟧ =

$\lambda i.\ \exists x_{<s,e>}\ [\ \forall y[\text{temp-Chicago}(y,i) \leftrightarrow x=y]\ \wedge$

$\exists z_{<s,e>}\ [\ \forall v[\text{temp-StLouis}(v,i) \leftrightarrow z=v]\ \wedge\ \forall i'' \leq i\ [x(i'') = z(i'')]\ ]\ ]$

e. ⟦ *Necessarily the temperature in Chicago 1 [the temperature in St. Louis 2 [always t_1 is t_2]]* ⟧ =

$\lambda i. \forall i' \in Acc(i)\ [\exists x_{<s,e>}\ [\forall y[\text{temp-Chicago}(y,i') \leftrightarrow x=y]\ \wedge$

$\exists z_{<s,e>}\ [\forall v[\text{temp-StLouis}(v,i') \leftrightarrow z=v]\ \wedge \forall i'' \leq i'[x(i'') = z(i'')]]]]$

[12] One could argue that world and time indices are kept distinct in the grammar (type s for worlds and type i for time intervals), that the actual type of the N’ at issue is <s,<<i,e>,t>>, and, thus, that different binders must target each slot. The point I want to

make here is that, even if we assume the type <s,<<s,e>,t>> and allow for double binding, we do not run into problems.

[13] Assuming that, for any situation index i" part of a world index i, ⟦*temperature in NP*⟧(i") yields the singleton containing the individual concept $x_{<s,e>}$ "recording" the temperature values in the entire world index i, (ia) is equivalent to (ib). Note that the assumption that ⟦*temperature in NP*⟧(i") yields a function defined for indices beyond i" (and/or its parts) is already presumed in Dowty, Wall and Peters (1981) and Lasersohn (2005), witness the model (16). Finally, (ib) is equivalent to (ic)/(38a) given the uniqueness of $x_{<s,e>}$ and $z_{<s,e>}$.

(i) a. $\lambda i.\ \forall i'' \leq i\ [\ \exists x_{<s,e>}\ [\ \forall y[\text{temp-Barcelona}(y,i'') \leftrightarrow x=y]\ \wedge$

$\exists z_{<s,e>}\ [\ \forall v[\text{temp-LA}(v,i'') \leftrightarrow z=v]\ \wedge x(i'')=z(i'')\ ]\ ]\ ]$ (=(40))

b. $\lambda i.\ \forall i'' \leq i\ [\ \exists x_{<s,e>}\ [\ \forall y[\text{temp-Barcelona}(y,i) \leftrightarrow x=y]\ \wedge$

$\exists z_{<s,e>}\ [\ \forall v[\text{temp-LA}(v,i) \leftrightarrow z=v]\ \wedge x(i'')=z(i'')\ ]\ ]\ ]$

c. $\lambda i.\ \exists x_{<s,e>}\ [\ \forall y[\text{temp-Barcelona}(y,i) \leftrightarrow x=y]\ \wedge$

$\exists z_{<s,e>}\ [\ \forall v[\text{temp-LA}(v,i) \leftrightarrow z=v]\ \wedge \forall i' \leq i\ [x(i'')=z(i'')]\ ]\ ]$ (=(38a))

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