Lifelong Discourse Representation Structure

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Abstract

We argue that the key to the solution of both the theoretical problem of working out a realistic picture of the "hearer's (permanently changing) information state" (abbr. HIS) within the framework of Discourse Representation Theory (DRT; van Eijck and Kamp, 1997) and the empirical problem of a wide range of classical formal-semantic puzzles (concerning the creation (or retrieval?) of referents for pronouns and definite descriptions in universal and belief contexts and in other special cases) lies in one and the same discovery: HIS is essentially to be regarded as a discourse representation structure, a gigantic "lifelong" DRS furnished with a partially ordered set of *worlds*, a (multiple) *cursor* (pointing to temporal, spatial and rhetorical reference points) and a *meaning function*. The structure we propose is based on three denumerably infinite set of *pegs* (in Landman's (1986) sense), those of *referents*, *predicate names* and *worlds*, whose inner structures and the rich system of connections among them are to be defined by simultaneous recursion (see the Appendix after References).

1. Dynamic perspective on semantics

Our starting-point is DRT (e.g. Kamp, 1981; Heim, 1983; van Eijck & Kamp, 1997), which we consider to be a successful attempt to extend the sentence-level Montagovian model-theoretic semantics (Dowty *et al.*, 1981), which had not only failed to exceed this level but had also been unsuccessful in the treatment of certain types of anaphoric relations, to the discourse level. Its essence lies in the discovery that the failure of the immediate interpretation of sentences / discourses in the static Montagovian world model is to be attributed to the fact that the discourse under interpretation is permanently becoming part of the world in which it is being interpreted; thus a level of discourse representation *must* be inserted in between the language to be interpreted and the world model serving as the context of interpretation. This *dynamic perspective* of DRT can be captured by regarding the content of DRSs as a "(partial) function mapping information states to information states" (Zeevat, 1991: 17).

Nevertheless, the picture of HIS in DRT and related dynamic theories (e.g. Groenendijk & Stokhof, 1990, 1991) is oversimplified and in certain areas simply counter-intuitive: practically (total) models are used as information states. In this approach atomic statements (e.g. 'Peter loves Mary') are to be held to be *tests*, which means that an assertion heard is supposed to be either corroborated or rejected. The typical case is excluded: to regard an assertion as a new piece of information for the hearer. (Another basic problem of DRT —the one concerning the compositional transition between syntax and DRS— is discussed in Alberti (1998, 1999))

Hearers, counter to the oversimplified picture sketched above, practically always have a partial knowledge. And nothing other than DRS serves the purpose of representing partial knowledge.

2. Lifelong DRS

The hearer's permanently changing information state can be defined by simultaneous recursion (see the table in Appendix).

We essentially regard this definition as a generalization of the (also simultaneously recursive) definition of DRSs given in van Eijck & Kamp (1997); or this original definition may be regarded as one suitable for discourses with an empty mutual background knowledge shared by speaker and hearer. This stipulation on background knowledge mentioned may often serve (or have served so far) as a useful working hypothesis — especially when DRT is compared to the Montagovian model-theoretic semantics— but it is undoubtedly far from being a realistic picture of discourses. Now it is high time, hence, to turn to the general situation on the basis of experiences and results obtained by studying the restricted area in the last two decades.

First of all, three denumerably infinite sets of *pegs* should be assumed to be at the hearer's disposal: those of *referents* (R), *predicate names* (P) and *worlds* (W). They are 'pegs' (Landman, 1986) in the sense that before use they contain no information, they are only carriers of information. The inner structure of these sets and the rich system of connections among them are due to six (partial) functions/relations:

[1] The expression "Lifelong DRS" is due to an anonymous reviewer of an earlier article of mine on the topic (Alberti 1996/1999), who was selected by Anna Szabolcsi, the guest-editor of *Acta Linguistica Hungarica*. I would like to thank both of them for the expression.

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i. The *extension of predicates* is a partial function ext : P → Pow(R*) from predicates to the powerset of referent sequences (* denotes the Kleene star).[2]

ii. Another partial function ref : R → Pow(P×R*) *(referent function)* assigns each referent in its domain a set of sequences consisting of a predicate name and referents; an element of Pow(P×R*) is essentially a basic kind of DRS.

iii. Relation prc *(precedes* or <) is a partial ordering in W×W with a least element, denoted by v (the *basic world).*

iv. wrl : (P ∪ R) → W is also a partial function *(world function);* it assigns a predicate name or a referent a world.

v. There is a *cursor,* a partial function cur : {W,R} → W∪R*, which chooses an *active* world (cur(W)) and a sequence of referents playing distinguished roles in different respects in the current state of the hearer's (permanently changing) information state: cur(R) = ⟨$cur_{temporal}$(R), $cur_{spatial}$(R), $cur_{rhetorical}$(R), ...⟩.

vi. There is also a *meaning function:* a partial function mea : P → Pow(P×R*). It maps a predicate name to a DRS (meaning postulates).

The starting-point of the simultaneously recursive definition of HIS as a sextuple <ext, ref, prc, wrl, cur, mea> is fixing a one-member base: <∅, ∅, ∅, ∅, cur(W)=v, ∅> where ∅ denotes the empty set. We propose seven kinds of recursive steps (Appendix); their names are intended to refer to their operation: *expansion (of extensions) of predicates* (EXP), *introduction of a new predicate* (INP), *cursor move* (CUM), *introduction of a new referent into the active world* (IREA) and *a new world* (IREN), *referent assignment to a (generalized) DRS* (RED). Observe the first four components of HIS (the LDRS) define a DRS: the usual box structure corresponds to the tree of worlds, and function wrl is responsible for linking referents to boxes. The recursive steps are to capture different linguistic and extralinguistic ways of gathering information at the hearer's disposal. The linguistic ways will be sketched below, and will be described as (certain combinations of) special cases of the above listed recursive steps.

3. Where is the referent?

Subsections 3.1-5. provide an informal sketch of the treatment of a couple of famous semantic puzzles in the approach based on defining HIS as a Lifelong DRS. The first subsection demonstrates the use of RED and the cursor-moving operation (CUM).

3.1. Referents, predicates, and then referents again

(1) shows the bidirectional connection between referents and predicates. On the one hand, we describe properties ('r2 ∈ pretty'), classes ('r1 ∈ boy') and relations ('⟨r1, r2⟩ ∈ ext(love)') of referents by means of predicates. On the other, we can also refer to "products" of this linguistic activity (RED) by means of referents ('admitted(r1,r3,r2)' where r3 is assigned to the situation expressed by the first sentence; and 'surprise(r4,r5)' where 'friend-of(r5,r1)' and ref(r4) essentially corresponds to the DRS expressing the information of the second sentence (according to a preferred reading)).

(1) The boy loves a pretty Dutch girl. He admitted IT to her. His friend was surprised by IT.

The sentence in (2a) below describes a strange custom whose (Davidsonian) referent r_{sc} belongs to, say, the basic world (v), whereas the farmer (r_f) and the donkey (r_d), and then the merchant (r_m) belong to "later" worlds: wrl(r_{sc})=v, wrl(r_f)=w1, wrl(r_d)=w1, wrl(r_m)=w2, where v<w1<w2, according to partial ordering prc. The alternative continuations (2b-d) can "activate" different worlds (v, w1 (+w3), w2, respectively) due to conjunctions, adverbs etc., which determines accessibility of referents (EXP, CUM, IREA, IREN and RED are concerned).

(2) a. If a farmer owns a donkey, HE sells IT to a merchant.
b. ... Mary is surprised at THIS STRANGE CUSTOM.
c. ... Or HE hires IT out to A FOREIGNER.
d. ... Although HE usually gets little money from HIM.

The participants of sentence (2b) belong to world v, including the referent of 'this strange custom' identical with the Davidsonian argument r_{sc} of sentence (2a). Sentence (2c), with 'or' as its first word, "accepts" participants of w1 (the farmer and the donkey) but, instead of world w2, it evokes a world w3, which the merchant (r_m) does not belong to but in which there is a 'foreigner': v < w1 < w3 (where w2 and w3 are incommensurable elements according to partial ordering prc), and wrl($r_{foreigner}$)=w3. Continuation (2d) makes the cursor choose world w2 (cur(W)=w2) due to the adverbial expression 'usually' referring to the generalizing / generic content of the conditional sentence in (2a); and it is in this world w2 that the merchant can be retrieved (by the pronoun 'him').

The most important law illustrated by these examples is that a referent r belonging to a world w can be referred to in worlds w' such that w'≥w. The farmer, for instance, but not the merchant, can be referred to in world w3 because v < w3, but w2 and w3 are incommensurable worlds.

(3a-c) show the same strategy in different areas: the first sentences "activate" a world (distinct from the basic world v), which remains active due to temporal/aspectual/etc. tools. These tools "retain" us in the world of the game (3a), of the typical convention where Harvey is present (3b), and of the speaker's wishes (3c).

(3) a. Every player chooses a pawn. HE puts IT on square one. (canonical scenario)
b. Harvey courts a girl at every convention. SHE is usually very pretty. (univ. quantifier)
c. I wish Mary had a car. Peter could drive IT / THE CAR too. (modal expression)

There may be even explicit references to worlds to be activated, as is shown below in (4) (CUM, IREN). 'The

[2] The mapping ext(love) = {⟨r_P,r_M⟩, ⟨r_M,r_P⟩, ⟨r_P,r_A⟩}, for instance, can be understood as follows: there is a HIS in which love ∈ P, and the r's are referents (corresponding to, say, persons named Peter, Mary and Ann), and the given hearer is assumed to know that Peter and Mary love each other, and Peter loves Ann, too. As HIS expresses partial knowledge, the hearer is not assumed to be sure that other people do not love each other.

first case' refers to a potential world with a secretary while 'the second case' makes another potential world active, which the gardener belongs to (the task of making coffee referred to by 'it' is assumed to belong to v). These two alternative (incommensurable) worlds are introduced due to the disjunctive structure in the first sentence.

(4) We ought to employ either a secretary or a gardener. In the first case THE SECRETARY would make coffee from now on, whereas in the second case IT would be Mary's task but THE GARDENER should sweep the yard.

3.2. Where is the referent that does not exist?

Due to RED, as in the case of (1), HIS after working up sentence (5a) below may contain the referent that 'this victory' in continuation (5b) is intended to retrieve. In continuations (5c-e), 'this victory' refers to different — underspecified— situations.

In (5c) 'the victory of our team A over the Spanish team' —*with no temporal anchor*— is referred to. Sentence (5d) is about 'the victory of *one of our teams* over the Spanish team.' Finally, 'this victory' in (5e) refers to 'an arbitrary victory of one of our teams over anybody.'

(5) a. Yesterday our team A won a victory over the Spanish team.
b. ... THIS VICTORY is marvelous.
c. ... Did not THIS VICTORY happen the day before yesterday?
d. ... I wish our team B could replicate THIS VICTORY today.
e. ... I wish our team B could replicate THIS VICTORY over the English today.

Operation RED enables us to create all the appropriate referents by means of the "generalization function" G mentioned in Appendix: G is to replace certain referents with "variables." More precisely, referents not used up earlier can be used as "variables," because such referents have not been individualized by any kind of information so predicating something of them is no more than making existential statements about them, and these existential statements are to be regarded as logical entailments of sentence (5a). Thus no new information is applied in the course of the replacement of referents carried out by partial function G — in harmony with the fact that no new information is at the hearer's disposal relative to his/her information state just after working up sentence (5a).

In the case of continuation (5d), for instance, where 'the victory of *one of our teams* over the Spanish team' is referred to, partial function G is to replace the referent belonging to team A with a non-individualized referent, which is a legitimate operation because statement (5a) implies that 'a team (of ours) has won a victory over the Spanish team.' The relevant entailment of (5a) in the case of continuation (5e) is that 'a team (of ours) has won a victory over another team,' and concomitantly partial function G is to substitute variable-like referents for both the referent of team A and that of the Spanish team.

Case (5c) shows that temporal referents must not have been ignored. Here the role of G amounts to substituting a variable-like referent for the referent belonging to the particular point of time when team A is assumed by the speaker to defeat the Spanish team.[3]

By now the case illustrated by continuation (5b) has become "extreme." Here partial function G required to calculate the reference of 'this victory' on the basis of the Davidsonian referent belonging to statement (5a) is to choose to be an empty function (whose domain is empty).[4]

HIS after working up the first sentence ((6a) below) in the following discourses contains no referent for a priest / dog. We claim, however, that the priest's referent can be created — by extending the mentioned stage of HIS without exploiting (really) new information, due to regarding HIS as a Lifelong DRS. That is what makes case (6) similar to the phenomenon illustrated by (5); but now not logically derivable existential entailments will be applied.

Here our starting-point is that it is a plausible assumption that a marriage is associated with a potential priest, but not with a dog, at least in Christian cultures. (6) warns us that this "association" does not amount to a logical implication but a *licensed* piece of cultural/encyclopedic knowledge (Kálmán, 1990), since it is not claimed in (6a) that the marriage was a religious one.

(6) a. Joe got married yesterday.
b. ... THE PRIEST spoke very harshly.
c. ... *THE DOG barked very loudly.

Operation SPED enables us to create the priest's referent, by applying it to the following pair of associated DRSs: <"x gets married," "y organizes x's marriage where y is a priest"> ∈ ASS, where ASS is one of the elements of the set P of predicates. This formula roughly means that if somebody gets married, it is typical that a priest organizes the ceremony. Note, however, that we do not regard it as being excluded that the same hearer's information state contains the following statement simultaneously: if somebody gets married, it is typical that a registrar organizes the ceremony.

As for technical details, here we need a "specifying function" S (see Appendix), which is to substitute Joe's particular referent for the "general" x (here variable-like referents are used again). This operation is permitted because the first member of the associated pair of DRSs mentioned above is considered to be true by the hearer with Joe's referent in the role of x (Joe got married indeed); and the crucial element of the result of the operation is as follows: the hearer (already) *thinks* that there is a priest who organized Joe's marriage in the precise sense of 'thinking' that this priest has a referent belonging to the basic world of HIS (or at least to a world preceding the fictive world that referent x belongs to).

One might think that (6c) can serve as a well-formed continuation of (6a) in an appropriate context. Suppose, for instance, that (the hearer knows that) Joe has a dog which barks loudly whenever it feels that its owner is in danger... This piece of information is to be regarded as part of some interpersonal knowledge at the hearer's disposal. It may be formulated by means of associated pairs of non-specific DRSs in the extension of relation

[3] This temporal referent should be replaced in cases (5d,e) as well.
[4] If G(r) is not defined, referent r is not to be replaced.

ASS, too; so the referent of the dog can be produced as the priest's one above.

The only difference lies in the source / nature of "mediating" information. The exploited information belongs to a supposed interpersonal knowledge in the case of (6c), to the hearer's cultural / encyclopedic knowledge in the case of (6b), and it is worth mentioning here that logical consequences were used in the case of the phenomenon illustrated by example (5). All these three kinds of information, together with the sort of information that can be referred to as 'lexical,' should be assumed to be stored in HIS in similar format, perhaps separated from each other, but all kinds should be accessible in the course of processing a discourse from sentence to sentence. In this way a wide range of phenomena is accounted for where "non-existing" referents should be "retrieved," or rather produced; and not only a certain referent is introduced as a result of our approach but the hearer commits him-/herself to a whole story that the given referent is a participant of (Kálmán 1990).[5]

3.3. Cursor

The temporal reference point changing from sentence to sentence, whose introduction (to DRT) is proposed by Kamp & Reyle (1993: 5.2.2), is very easy to capture in LDRS. It can be defined as a "cursor" pointing to the currently active temporal referent. We are going to argue that it would be useful to use at least four cursors, or lesser cursors with multiple values.

First of all, we need a *world cursor*, a function that assigns the set W of worlds a distinguished world, which can be called to be 'active' in the current state of HIS. As was mentioned in passing in subsection 3.1., antecedents of expressions in a sentence processed are to be sought among referents belonging to the active world or preceding worlds. The movement of this cursor can be described (and restricted) according to the partial ordering prc of worlds. Certain linguistic factors seem to make the cursor remain at a world or turn to another world *adjacent* to the last active world according to the partial ordering of worlds

There are extralinguistic factors, however, that seem to make the cursor choose a world independently of its last value. When two people enter into conversation with each other, for instance, they should "activate" the worlds in their LDRSs carrying their shared interpersonal knowledge. It can be accounted for in this way why a question like "What about Peter" cannot be interpreted in certain situations whilst it is perfect in other situations without any special introductory discourse. The problem is not that the given hearer knows no Peter or more Peters; practically every hearer can be assumed to know several Peters. This fact, however, does not imply that the question discussed will always be ill-formed. The question will obviously prove to be perfect if, and only if, a single referent named Peter happens to belong to the *active* world of the conversation.

Revealing rules of movement of the world cursor requires much future research, of course. What is claimed here is that furnishing traditional DRSs with a cursor pointing to a distinguished "box" is a promising idea; and what makes this picture realistic is that DRSs with this cursor are assumed to belong to the hearer interpreting a discourse, and not to the discourse itself, which is the essence of the LDRS approach.

Let us return to the kind of cursor corresponding to Kamp & Reyle's (1993) temporal reference point. Discourse (7a) below, similar to one analyzed by the authors mentioned above (p526), serves as an illustration of our approach. Now we need a cursor whose values are temporal reference points. It can be defined as a function from the set R of referents which chooses one referring to a point of time, which can be denoted by $cur_{temp(oral)}(R)$.

(7) a. A man entered the White Hart. Bill served him a beer. The man paid.

After processing the first sentence, which describes an event, the cursor takes the referent r_{enter} of the point of time when the man entered the pub as its value. Then let r_{serve} denote the time of the event of Bill's serving him a beer. Kamp & Reyle's (1993) statement on discourses consisting of events can be paraphrased in the framework of LDRS as follows: the temporal referent of the new event (chronologically) follows the active temporal referent. In the case discussed, hence, $r_{enter} = cur_{temp}(R) < r_{serve}$. For the third sentence, then, r_{serve} will serve as an active temporal reference point, and we obtain on the basis of the generazation mentioned above: $r_{serve} = cur_{temp}(R)' < r_{pay}$.

Other kinds of relevant reference points can be obtained by a straightforward generalization of the cursor function demonstrated above. Let cur(R) be defined as a vector of referents with the active temporal value as its first element. Then a spatial reference point may occupy the second position, to be denoted by $cur_{spat(ial)}(R)$. We can formulate rules such that, after processing a sentence describing a movement, the referent of the place associated with the *goal* thematic role will serve as the spatial cursor value. In example (7a), thus, the event described by the second sentence is understood to take place in the pub named White Hart, which is the goal of the entering event described in the first sentence. That is, the beer mentioned in the second sentence is served in this pub (at least that is the default reading). The paying event that the third sentence describes is also to be understood to take place in the same pub (according to the preferred reading) because the second sentence triggers no shift in active spatial referent (suppose the man getting the beer has a beneficiary role in the serving situation, and not a goal role).

Topic shift, illustrated below in (7b) by a Hungarian example (Pléh, 1982), is a further phenomenon that can be accounted for by means of the referent cursor. This third

[5] An anonymous reviewer of an earlier version of this paper has considered this method of producing referents to be too productive (at least from a practical point of view). What I accept is that some additional tool is required but I retain that the kinds of phenomena discussed in the subsection require HIS to contain the pieces of information of different nature stored in some way or another. The additional tool can be some kind of (also permanently changing) *weighing* sensitive to the (frequency or temporal distribution of) use of associative connections in the domain of relation ASS. Thus a model of oblivion should be worked out. Continuation (6c) is well-formed, for instance, only if the hearer happens to be clearly aware of the interpersonal piece of information that Joe has a single special dog. Cultural / encyclopedic pieces of knowledge, however, belong to a more stable sphere of the content of HIS.

element of cur(R) can be called the 'active rhetorical referent' ($cur_{rhet(orical)}(R)$).

(7) b. $Anna_i$ megverte $Marit_j$. A következõ percben $pro_{i/*j}$ / $AZ_{j/*i}$ sírni kezdett. Aztán $pro_?$ hazament.
Anna hit Mari-acc. The following minute-in pro/that weep-inf began. Then home-went.
'Ann hit Mary. In the following minute she burst into tears. Then she went home.'

The "dropped" pronoun in the second sentence is to be interpreted as referring to the person referred to by the topic / subject of the first sentence whereas the explicit demonstrative pronoun can refer to the other participant mentioned in the first sentence, yielding "topic shift." The referent of the dropped pronoun (pro) in the third sentence is unambiguously determined by the particular form of the second sentence: it is identical with the referent of the subject of the second sentence; thus there is no topic shift between the second and the third sentence.

These observations are easy to account for by means of the rhetorical cursor value. After processing the first sentence, the referent belonging to its subject / topic is to be chosen to play the role of the active rhetorical referent. As for fixing the referent of the subject of the second sentence, the following general rule seems to be valid: a dropped pronoun retrieves the active rhetorical referent whilst the task of a demonstrative pronoun is just the opposite: its referent is to differ from the active rhetorical referent, causing topic shift. This is a straightforward case of division of labor between alternative linguistic expressions. The interpretation of the third sentence corroborates the rule formulated above: there is no topic shift, i.e. the referent of its dropped pronoun is identical with the active rhetorical referent after processing the second sentence, which, however, depends on the choice between the two versions in the subject position of the second sentence.

3.4. Each other's belief referents

We follow Zeevat (1991: 20) in assuming that "...making the assumption that one can refer to private objects and that the idea of a private model can be worked out suffices for dealing with most of the classical belief puzzles. The contribution of DRT in this respect is to supply a theory about the structure of this private model and a set of rules for the evolution of this private model under the influx of new information." LDRS is obviously an attempt to work out the "private model" Zeevat is speaking about.

Let us study the following famous example of Geach's in order to illustrate one of the most stubborn kind of belief problems. The problem lies in the fact that it is difficult to account for the *coreference* between 'a witch' and 'she' in a traditional logic because neither witch exists so neither has a "normal" referent.

(8) Hob thinks that a witch poisoned his pig and Nob thinks that SHE killed his goat.

In our approach, the hearer may have a world (presumably not the basic one) where Hob's witch's referent can be found and it may be assumed to coincide with that of Nob's witch, since it is a straightforward assumption that their beliefs rely on the same rumor. Furthermore, people can be assumed to be able to link each other's corresponding referents together in conversations. The game named Quiz or Twenty Questions serves as clear evidence: two people begin to speak about something entirely unknown to one of them. Almost the only thing they know is that they are speaking about the *same* entity; that is, new pieces of information should be associated with one and the same referent, marked out at the beginning, throughout the whole game.

Let us highlight the crucial element of our approach based on regarding hearers' information states as LDRSs. As was shown in 3.1., "verbal products," created in the course of talking to each other, can be referred to as easily as perceived entities of the real world around us; and the same holds true of hearers' information states: referents in them can also be referred to. A HIS is like a painting or a map in this sense: its details can be talked about.

3.5. Meaning function and Qualia Structures

Pustejovsky's (1995, 129) *long record* is intended to illustrate the promising possibility for embedding his Qualia Structures (or something similar) —together with the explanatory capacity of this theory— in LDRSs.

(9) John bought A LONG RECORD.

What Pustejovsky questions is that the semantic content of the expression in question is to be captured by the (simplified) logical formula $long(x) \wedge record(x)$, which a simple DRS representing the content of the expression could be based on, too. We are arguing that Pustejovsky's argumentation according to which the given meaning of *long* is not reasonable to store in a constant (core) lexicon can be reconciled with an LDRS-compatible approach in which the human sentence-to-sentence processing is assumed to "generate" temporary extended lexicons relative to which the above mentioned simple formula can be retained.

Suppose the proper meaning of *long* is not at the hearer's disposal at a certain point (HIS1) of working up sentence (9): (s)he tries to construct the appropriate DRS from pieces like 'bought(r1, r2),' 'record(r2),' '$long_i$(r2),' but there is no proper index i. Hence, HIS1 has to be extended to another HIS (without exploiting new information), as in the cases discussed in section 3.2. Although now it is not a referent that is being sought / produced, firstly a referent can be found on the basis of a piece of cultural information: that of the playing time of the record, for which, say, '$long_{17}$(r3)' is semantically well-formed, where 'playing-time-of(r3,r2).' Note that a certain property of *polysemy* helps find the predicate we have happened to mark with 17: the phonetic form of this predicate is identical with that of the (still) unknown one.

And now the hearer knows not only what is *long* but what the intended meaning of $long_i$ has been. (S)he may assign a new predicate peg to this predicate, denoted by, say, $long_{147}$, and (s)he may define $mea(long_{147})$ on the basis of $long_{17}$ and the connection discovered (INP).

4. Summary

It has been argued in this article that the key to the solution of both the theoretical problem of working out a realistic picture of the hearer's (permanently changing) information state within the framework of Discourse Representation Theory and the empirical problem of a wide range of classical formal-semantic puzzles lies in one and the same discovery: HIS is essentially to be regarded as a discourse representation structure, a gigantic Lifelong DRS furnished with a partially ordered set of worlds, a (multiple) cursor (pointing to temporal, spatial and rhetorical reference points) and a meaning function.

LDRS can be regarded as a generalized version of DRS and can (also) be defined by simultaneous recursion. Three denumerably infinite sets of peg-like elements are assumed to be at the hearer's disposal as a starting-point (in addition to an empty $LDRS_0$, corresponding to the moment of the ideal hearer's birth): those of referents, predicate names and worlds. The inner structure of these sets and the rich system of connections among them are due to six (partial) functions/relations; their definitions are based on the simultaneously recursive technique mentioned above (Section 2 and Appendix).

Section 3 has provided a sketchy review of the treatment of a couple of famous semantic puzzles in the approach based on defining HIS as a Lifelong DRS.

Subsection 3.1. has been devoted to the discussion of problems concerning +/– accessibility of referents from given (partly fictive) worlds evoked by certain parts of discourses.

3.2. has dealt with questions concerning the retrieval, or rather construction or calculation, of "non-existing" referents on the basis of logical, lexical, cultural / encyclopedic and/or interpersonal pieces of "mediating" information, all kinds to be assumed to be stored in HIS in similar format and to be accessible in the course of processing a discourse from sentence to sentence.

3.3. has contained arguments for the introduction of a cursor pointing to the active world, distinguished temporal and spatial reference points, and an "active rhetorical referent" playing a crucial role in accounting for topic-shift phenomena.

In 3.4. we have argued that most of the classical belief puzzles can be treated in LDRS due to our approach according to a person's information state, including her/his beliefs and wishes, is like a painting or a map in the sense that its details can be talked about and referred to by referents (of no special status).

Finally, 3.5. has demonstrated the possibility for embedding a Pustejovskyan (1995) multistratal "generative lexicon" in our extended theory of discourse representation.

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name	EXTENSION OF PREDICATES ext: $P \rightarrow Pow(R^*)$	ASSIGNMENT OF REFERENTS ref: $R \rightarrow Pow(P \times R^*)$	TREE OF WORLDS $prc \subset W^2$ (prc = <)	ASSIGNMENT OF WORLDS $wrl : (P \cup R) \rightarrow W$	CURSOR $cur: \{W,R\} \rightarrow W \cup R^*$	MEANING POSTULATE $mea : P \rightarrow Pow(P \times R^*)$	comments
base ($LDRS_0$)	$ext(p) = \emptyset$ $(\forall p)$	$ref = \emptyset$	$prc = \emptyset$	$wrl = \emptyset$	$cur(W) = v$, $cur(R) = ?$	$mea = \emptyset$	ref, wrl and mea are partial orders
1. **EX**PANDING **P**REDICATE (1st row: condition)	$ext'(p) \neq \emptyset$			$cur'(W) \geq wrl'(p)$ $cur'(W) \geq wrl'(r_i)$		mea'(p) exists	$pr_1r_2...r_n$ is a statement
EXP (2nd row: definition)	$ext(p) =$ $ext'(p) \cup \{r_1r_{2...}r_n\}$				permitted : $cur(W) \neq cur'(W)$ $cur(R) \neq cur'(R)$, depending on p and its distinguished arg's	mea'(p) ≠ mea(p) is permitted	there is a subgroup of distinguished predicates in P: e.g. ASS, ⇒, ∈, "I-believe"
2. **IN**TRODUCTION OF A NEW **P**REDICATE	$ext'(p) = \emptyset$			$cur'(W) \geq wrl'(r_i)$, wrl'(p) does not exist		mea'(p) does not exist (mea'(q) exists)	
INP	$ext(p) = \{r_1r_{2...}r_n\}$			$wrl(p) = cur(W)$	permitted : $cur(W) \neq cur'(W)$ $cur(R) \neq cur'(R)$, depending on p and its distinguished arg's	mea(p) (already) exists	there are relations in P to provide information on associated phon. forms
3. **C U**RSOR **M**OVE							cursor moves backwards...
CUM			cur'(W) and cur(W) are adjacent acc. to partial order prc				...or forwards due to ±linguistic factors
4. **I**NTRODUCTION OF A NEW **RE**FERENT INTO THE **A**CTIVE WORLD				wrl'(r) does not exist			
IREA			$cur(W) = cur'(W)$	$wrl(r) = cur(W)$			
5. **I**NTR. OF A NEW **RE**FERENT INTO A **N**EW WORLD			v and w are incommensurable acc. to partial order prc'	wrl'(r) does not exist, $wrl'^{-1}(W)$ is empty			
IREN			$cur'(W) < cur(W) = w$, and they are adjacent acc. to prc	$wrl(r) = cur(W)$			
6. **RE**FERENT ASSIGNMENT TO A (GENERALIZED) **D**RS	$r_{1,1}...r_{1,arg(p1)} \in ext'(p_1)$, ... $r_{k,1}...r_{k,arg(pk)} \in ext'(p_k)$			wrl'($G(r_{ij})$) do not exist			$G \subset R^2$ is a partial function ($G \cap id = \emptyset$): "generalizing function"
RED	$G(r_{1,1}...r_{1,arg(p1)}) \in ext(p_1)$, ... $G(r_{k,1}...r_{k,arg(pk)}) \in ext(p_k)$	$ref(r) = G(\{p_1r_{1,1}...r_{1,arg(p1)}$, ..., $p_kr_{k,1}...r_{k,arg(pk)}\})$		$wrl(G(r_{ij})) \geq cur(W)$			(where id is the identity function of set R)
7. **SPE**CIFICATION OF AN ASSOCIATED **D**RS	$<q,s> \in ext'(ASS)$, and $\exists S$: $S(r_{q1,1}...r_{q1,arg(pq1)}) \in ext'(p_{q1})$ ... $S(r_{qk,1}...r_{qk,arg(pqk)}) \in ext'(p_{qk})$	$ref'(q) = \{p_{q1}r_{q1,1}...r_{q1,arg(pq1)}$ ..., $p_{qk}r_{qk,1}...r_{qk,arg(pqk)}\}$, $ref'(s) = \{p_{s1}r_{s1,1}...r_{s1,arg(ps1)}$, ..., $p_{sm}r_{sm,1}...r_{sm,arg(psm)}\}$,		we need an "appropriate" S' (which replaces only "variables")		formula ASS(q,s) belongs to mea(p)	
SPED	$S(r_{s1,1}...r_{s1,arg(ps1)}) \in ext(p_{s1})$, ..., $S(r_{sm,1}...r_{sm,arg(psm)}) \in ext(p_{sm})$, where $S' \subseteq S$			"appropriate" S (which replaces certain "variables" with non-used referents in cur(W))			now $S \subset R^2$ is a "specifying" function

Appendix. Table 1: (simultaneously recursive) definition of LDRS (Lifelong Discourse Representation Structure)