# Computing Perspective in Dialogue

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**Abstract.** A computational reconstruction of communication in dialogue requires not only an analysis of language expressions, but of *utterances*. In DBS, an utterance is defined as (i) a propositional content and (ii) a cluster of pointers called STAR. The STAR serves to anchor a content to the interpretation's parameter values of Space, Time, Agent, and Recipient. The STAR also provides the referents for a certain kind of sign in natural language, namely the *indexical*.

In this paper, three different STARs are used to code three different perspectives on content: (i) the STAR-0 for coding the agent's perspective on non-language content resulting from recording current recognition and action, (ii) the STAR-1 for coding the speaker's perspective on content underlying language production, and (iii) the STAR-2 for coding the hearer's perspective on content resulting from language interpretation. It is shown that the computation of these perspectives by means of DBS inferences is completely software mechanical.

**Keywords.** Statement, question, request, indexical, STAR, Database Semantics, Conversion Universals, DBS inferences

## 1. Agent's Perspective on Current Non-Language Content

English has five indexical pointers which are used to refer to (1) the speaker, as in I, we, (2) the hearer, as in you, (3) an agent or object other than the speaker and the hearer, as in he, she, it, they, this, (4) the present moment, as in now, and (5) the present location, as in here. The referent of an indexical is determined by the *origin* of the sign containing it, represented as the STAR of the sign's utterance.

However, before a content can be uttered in natural language it must emerge as non-language content in the agent's cognition. Non-language content recording the agent's current situation is anchored to the STAR-0. The following example illustrates an anchored content resulting from recording an activity self-performed by the agent:

### *1.1. Example of an anchored non-language content*

I am writing you a letter.$^{\mathrm{STAR-0}}$

In this informal representation, the content is specified in two parts:[1] (i) a sentence of English, used as an aid to represent a non-language content, and (ii) a STAR-0, added as

[1] The distinction between a content and its anchor may be applied to any system recording its current state. Systems may differ, however, with respect to the attributes and the range of values of their anchor. In avionics and air traffic control, for example, the anchor would use attributes like ground location, height, speed, and direction (*situation awareness*, Endsley et al. 2000, 2003) rather than space, time, author, and recipient.

a superscript at the end.[2] The content represented by the English sentence alone is called an *un-anchored* content. In DBS it is coded as the following set of proplets:

*1.2. Coding un-anchored content as a proplet set*

| | | | |
|---|---|---|---|
| noun: moi[3] | verb: write | noun: toi | noun: letter |
| fnc: write | arg: moi, toi, letter | fnc: write | fnc: write |
| prn: 659 | prn: 659 | prn: 659 | prn: 659 |

A proplet is defined as a non-recursive (flat) feature structure with ordered attributes. The proplets of a propositional content are an order-free set held together by a common prn (for proposition number) value, here 659. The functor argument structure of the content is coded by the values of the fnc (for functor) and the arg (for argument) attributes (bidirectional pointering).

The values of the associated STAR-0 may be specified as follows:

*1.3. Specification of a STAR*

S = Paris
T = 1930-07-03
A = J.-P. Sartre
R = S. de Beauvoir

While the value of the A attribute is constant for any individual agent, the value of the T attribute is continuously changing with time. The values of the S andR attributes may also change. Therefore, an un-anchored content must be connected to the current STAR-0 as soon as the content emerges.

The connection between an un-anchored content and its STAR-0 is formally established by defining the STAR-0 as a proplet with the same prn value as the associated propositional content. The following example complements the un-anchored proplet representation 1.2 with the STAR-0 anchor 1.3:

*1.4. STAR-0 content*

| | | | | |
|---|---|---|---|---|
| noun: moi | verb: write | noun: toi | noun: letter | S: Paris |
| fnc: write | arg: moi, toi, letter | fnc: write | fnc: write | T: 1930-07-03 |
| prn: 659 | prn: 659 | prn: 659 | prn: 659 | A: J.-P. Sartre |
| | | | | R: S. de Beauvoir |
| | | | | prn: 659 |

This nonlanguage content constitutes a perspective insofar as J.-P. is looking out towards his current location S, his current moment of time T, himself as an agent in the world A, and Simone as his partner of discourse R. As indexicals, moi and toi[4] are defined to point at the A and R values, respectively, of the STAR-0.

[2]This notation is reminiscent of Montague's (1974) use of "indices." However, while the @,i,j,g index cluster in Montague's PTQ refers to a set-theoretically defined model structure, the STAR refers to the agent-external real world, including the agent viewed from the outside.

[3]We are using moi and toi instead of I and you because I is not sufficiently distinctive typographically.

[4]In real life, J.-P. Sartre and S. de Beauvoir addressed each other with vous. This relates to the register of honorifics, which is highly grammaticalized in Korean and Japanese, for example. As a socially important aspect of perspective, the register of honorifics (politeness) must be integrated into the R value of the STAR.

An agent may also register an observation without any self-reference or involvement of a recipient, as in the following example.

*1.5. STAR-0 content without indexicals*

| noun: Fido | verb: bark | S: Paris |
|---|---|---|
| fnc: bark | arg: Fido | T: 1930-07-03 |
| prn: 572 | prn: 572 | A: S. de Beauvoir |
| | | prn: 572 |

In this anchored non-language content, Simone notes that Fido is barking. Because the content contains no indexical pointing at the R attribute, this feature may be omitted in the STAR-0 specification.

Alternatively to referring to Fido by name, Simone could have used the 3rd person index ça,[5] as in the following example:

*1.6. STAR-0 content with a third-person index*

| noun: ça | verb: bark | S: Paris |
|---|---|---|
| fnc: bark | arg: ça | T: 1930-07-03 |
| prn: 572 | prn: 572 | A: S. de Beauvoir |
| | | 3rd: Fido |
| | | prn: 572 |

The indexical ça is defined to point at the value of the 3rd attribute of the STAR-0. In contradistinction to 1.5, the reference to Fido is not by name here, but by indexical.

For STAR-0 contents, the attributes R and 3rd are optional in that their values need only be defined if the content contains toi and ça pointers, respectively. For STAR-1 contents (speak mode) and STAR-2 contents (hear mode), a value for the R attribute is obligatory; in small children, the R value may be viewed as fixed to the mother.

In summary, values for S, T, and A attributes in the STAR are obligatory for all anchored contents. Thereby a rough idea of the location, of the date and the time of day, and of oneself will usually suffice for all practical purposes. Loss of the STA parameter values for any length of time, however, results in complete disorientation of the agent.

## 2. Speaker's Perspective on Content to be Mapped into Language

The next day (T: 1930-07-04), Simone and J.-P. meet in the Café de Flore on the Left Bank. To get the conversation going, J.-P. begins a *statement dialogue* by uttering the following declarative sentence to her (in French):

[5] In the FoCL'99 definition of the STAR, the attribute 3rd providing the referent value for the third person pointer ça was not included because it does not participate directly in anchoring a sign's content. It is necessary, however, for the interpretation of indexicals like this and indexical (i.e., non-coreferential) uses of he, she, it, etc. Rather than changing the terminology from STAR to STAR3rd, we will continue with the simpler term STAR, but use the attribute 3rd and the value ça for third person indexicals when needed (e.g., 1.6).

*2.1. Example of a STAR-1 expression with indexicals*

I wrote you a letter yesterday.$^{\mathrm{STAR-1}}$

At this point, J.-P. is dealing with two STARs, (i) the STAR-0 defined in 1.3 and used in the anchored content 1.4 and (ii) the STAR-1 for the utterance indicated in 2.1. The S, A, and R values of these two STARs in J.-P.'s mind happen to be the same,[6] but the T values differ. This difference constitutes a second kind of perspective: J.-P. is looking back onto a content created in his mind in the recent past. The English surface of 2.1 reflects this perspective by means of (i) the past tense form of the finite verb and (ii) the adverbial modifier yesterday.

At the level of content, the automatic coding of the speaker perspective is based on the following DBS inference (cf. Hausser 2010a), called STAR-1.1, which takes the speaker's current STAR-1 and an anchored STAR-0 content like 1.4 as input:

*2.2. STAR-1.1 inference for temporal specification*

$$\begin{bmatrix}\text{verb: } \alpha \\ \text{prn: K}\end{bmatrix}\begin{bmatrix}\text{S: L}\\ \text{T: D}\\ \text{A: N}\\ \text{R: O}\\ \text{prn: K}\end{bmatrix}\begin{bmatrix}\text{S: L}'\\ \text{T: D}'\\ \text{A: N}\\ \text{R: O}'\\ \text{prn: K+M}\end{bmatrix} \Rightarrow \begin{bmatrix}\text{verb: } \alpha\\ \text{sem: } \beta\\ \text{mdr: } \gamma\\ \text{prn: K+M}\end{bmatrix}\begin{bmatrix}\text{adj: } \gamma\\ \text{mdd: } \alpha\\ \text{prn: K+M}\end{bmatrix}\begin{bmatrix}\text{S: L}'\\ \text{T: D}'\\ \text{A: N}\\ \text{R: O}'\\ \text{prn: K+M}\end{bmatrix}$$

If D < D′, then $\beta$ = past, and if D diff D′ = 1 day, then $\gamma$ = yesterday; and similarly for all the other possible temporal relations between a STAR-0 and a STAR-1 differing in their T value.

In the input schema, an anchored STAR-0 content is represented by patterns for a verb and a STAR-0 which share the prn variable K (first two proplets). This anchored STAR-0 content is re-anchored to the speaker's current STAR-1 with the prn value K+M (third proplet); its S, T, and R values L′, D′, and O′, respectively, are potentially different from those of the STAR-0 (though the A value N must be the same).

The output is represented by a modified pattern for the verb, an additional proplet pattern for an (optional) adverbial modifier, and the STAR-1 pattern. The restrictions on the variables $\beta$ and $\gamma$ are used to control the tense and the temporal adverbial specified in the output schema of the inference.

Applying the inference STAR-1.1 to (i) J.-P.'s current STAR-1 and (ii) the STAR-0 content 1.4 results in the following STAR-1 content of the speak mode:

*2.3. STAR-1 content Moi* wrote *toi* a letter yesterday.

$$\begin{bmatrix}\text{noun: moi}\\ \text{fnc: write}\\ \text{prn: 659+7}\end{bmatrix}\begin{bmatrix}\text{verb: write}\\ \text{arg: moi, toi, letter}\\ \text{sem: past}\\ \text{mdr: yesterday}\\ \text{prn: 659+7}\end{bmatrix}\begin{bmatrix}\text{noun: toi}\\ \text{fnc: write}\\ \text{prn: 659+7}\end{bmatrix}\begin{bmatrix}\text{noun: letter}\\ \text{fnc: write}\\ \text{prn: 659+7}\end{bmatrix}\begin{bmatrix}\text{adj: yesterday}\\ \text{mdd: write}\\ \text{prn: 659+7}\end{bmatrix}\begin{bmatrix}\text{S: Paris}\\ \text{T: 1930-07-04}\\ \text{A: J.-P. Sartre}\\ \text{R: S. de Beauvoir}\\ \text{prn: 659+7}\end{bmatrix}$$

[6] For simplicity, the difference in location between J.-P.'s apartment and the Café de Flore within Paris is not reflected by the STARs' S values. Also, whole days are used for the T values. This *soft* treatment of the spatio-temporal coordinates is more appropriate for modeling a natural agent's cognition than the unnaturally precise values provided by the natural sciences, though they may be used if needed.

Compared to 1.4, the sem attribute of the verb has received the value past, and the adverbial modifier yesterday has been added as a proplet connected to the verb. Also, the new prn value 659+7 has been assigned by the parser not just to the verb and the adj proplet matched by the output schema of the STAR-1.1 inference, but to all proplets of the resulting content.

Assigning a new prn value, STAR-1.1 produces a new proposition by matching the antecedent pattern to stored content and deriving a new proposition as output which is written to the *now front* of the agent's Word Bank.[7] Thus, the original content and its STAR-0 are not overwritten. They may be retrieved by using the first part of the new content's prn value, here 659.

In addition to the temporal re-specification provided by the STAR-1.1 inference there must be a STAR-1.2 inference for a possible re-specification of the S value and a STAR-1.3 inference for a possible re-specification of the R value. For example, if J.-P. were to meet Juliette instead of Simone at the Café de Flore, the R value of his STAR-1 would be Juliette and the content of 1.4 would be realized as I wrote Simone a letter yesterday. The STAR-1.3 inference is defined as follows:

*2.4. STAR-1.3 inference for specification of recipient*

$$\begin{bmatrix}\text{verb: } \alpha\\ \text{arg: \{X toi\}}\\ \text{prn: K}\end{bmatrix}\begin{bmatrix}\text{noun: toi}\\ \text{fnc: } \alpha\\ \text{prn: K}\end{bmatrix}\begin{bmatrix}\text{S: L}\\ \text{T: D}\\ \text{A: N}\\ \text{R: O}\\ \text{prn: K}\end{bmatrix}\begin{bmatrix}\text{S: L}'\\ \text{T: D}'\\ \text{A: N}\\ \text{R: O}'\\ \text{prn: K+M}\end{bmatrix} \Rightarrow \begin{bmatrix}\text{verb: } \alpha\\ \text{arg: \{X O\}}\\ \text{prn: K+M}\end{bmatrix}\begin{bmatrix}\text{noun: O}\\ \text{fnc: } \alpha\\ \text{prn: K+M}\end{bmatrix}\begin{bmatrix}\text{S: L}'\\ \text{T: D}'\\ \text{A: N}\\ \text{R: O}'\\ \text{prn: K+M}\end{bmatrix}$$

The first three pattern proplets of the antecedent match the STAR-0 content 1.4. The consequent (output pattern) replaces toi by the R value O of the STAR-0 and assigns the prn value of the STAR-1. The [arg: {X toi}] specification in the input verb pattern is intended to match toi as subject or object. In this way, the inference may result in contents like I wrote Simone a letter as well as Simone wrote me a letter.

Applying STAR-1.1 and STAR-1.3 to 1.4 results in the following content:

*2.5. STAR-1 content Moi* wrote Simone a letter yesterday.

$$\begin{bmatrix}\text{noun: moi}\\ \text{fnc: write}\\ \text{prn: 659+7}\end{bmatrix}\begin{bmatrix}\text{verb: write}\\ \text{arg: moi, Simone, letter}\\ \text{sem: past}\\ \text{mdr: yesterday}\\ \text{prn: 659+7}\end{bmatrix}\begin{bmatrix}\text{noun: Simone}\\ \text{fnc: write}\\ \text{prn: 659+7}\end{bmatrix}\begin{bmatrix}\text{noun: letter}\\ \text{fnc: write}\\ \text{prn: 659+7}\end{bmatrix}\begin{bmatrix}\text{adj: yesterday}\\ \text{mdd: write}\\ \text{prn: 659+7}\end{bmatrix}\begin{bmatrix}\text{S: Paris}\\ \text{T: 1930-07-04}\\ \text{A: J.-P. Sartre}\\ \text{R: Juliette}\\ \text{prn: 659+7}\end{bmatrix}$$

The derivation of STAR-1 contents does not interfere with the cycle of natural language communication, because it applies after the activation of content for language production by LA-think and prior to the LA-speak derivation of a corresponding surface.

[7] This is in concord with the content-addressable database of a Word Bank, in which content is written once and never changed (cf. Hausser 2010b). The antecedent of a DBS inference may only read stored content, while the consequent may only write to the *now front* of the Word Bank – as reflected by the prn values of the DBS inferences 2.2 and 2.4.

## 3. Hearer's Perspective on Content resulting from Language Interpretation

When Simone hears the utterance 2.1, she does a standard time-linear hear mode derivation, resulting in the following set of proplets:

*3.1. Result of analyzing 2.1 in the hear mode*

| noun: moi | verb: write | noun: toi | noun: letter | adj: yesterday |
|---|---|---|---|---|
| fnc: write | arg: moi, toi, letter | fnc: write | fnc: write | mdd: write |
| prn: 623 | sem: past | prn: 623 | prn: 623 | prn: 623 |
| | mdr: yesterday | | | |
| | prn: 623 | | | |

Resulting from a strictly surface compositional analysis of the incoming surface, the content 3.1 represents the perspective of the speaker J.-P. – except for the prn value 623, which equals that of Simone's current STAR.

In the hear mode, the following main perspectives[8] on incoming speak mode content must be distinguished:

*3.2. Hear mode perspectives on language content*

1. The perspective of the hearer as the partner in face to face communication
2. The perspective of someone overhearing a conversation between others
3. The perspective of a reader on the content of a written text

Given that Simone and J.-P. are partners in face to face communication, the correct way for Simone to convert J.-P.'s speak mode perspective is from

I wrote you a letter yesterday.$^{\mathrm{STAR-1}}$

to her own hear mode perspective as

You wrote me a letter yesterday.$^{\mathrm{STAR-2}}$

This automatic conversion is based on the STAR-2.1 inference (see 3.3 below), which takes a content like 3.1 and a STAR-1 as input. The STAR-1 is *attributed* by the hearer to the speaker. In face to face communication, this is easy because the speaker's STAR-1 and the hearer's STAR-2 correspond in that the S and T values are the same, and the A and R values are reversed. The DBS inference STAR-2.1 is defined as follows:

*3.3. STAR-2.1 inference deriving hear mode perspective in face to face communication*

| noun: moi | verb: $\alpha$ | noun: toi | S: L |
|---|---|---|---|
| fnc: $\alpha$ | arg: { X moi toi} | fnc: $\alpha$ | T: D |
| prn: K | prn: K | prn: K | A: N |
| | | | R: O |
| | | | prn: K |

$\Rightarrow$

| noun: toi | verb: $\alpha$ | noun: moi | S: L |
|---|---|---|---|
| fnc: $\alpha$ | arg: { X moi toi} | fnc: $\alpha$ | T: D |
| prn: K | prn: K | prn: K | A: O |
| | | | R: N |
| | | | prn: K |

In the output, the speaker's STAR-1 perspective is revised into the hearer's current STAR-2 perspective by inverting the A and R values N and O, and keeping the S, T, and prn values.

Assuming that the STAR-2 used by Simone is [S: Paris], [T: 1930-07-04], [A: Simone], and [R: J.-P.], application of the inference STAR-2.1 to content 3.1 results in the following STAR-2 content:

*3.4. STAR-2 content Toi* wrote *moi* a letter yesterday.

$$\begin{bmatrix}\text{noun: toi}\\ \text{fnc: write}\\ \text{prn: 623}\end{bmatrix}\begin{bmatrix}\text{verb: write}\\ \text{arg: toi, moi, letter}\\ \text{sem: past}\\ \text{mdr: yesterday}\\ \text{prn: 623}\end{bmatrix}\begin{bmatrix}\text{noun: moi}\\ \text{fnc: write}\\ \text{prn: 623}\end{bmatrix}\begin{bmatrix}\text{noun: letter}\\ \text{fnc: write}\\ \text{prn: 623}\end{bmatrix}\begin{bmatrix}\text{adj: yesterday}\\ \text{mdd: write}\\ \text{prn: 623}\end{bmatrix}\begin{bmatrix}\text{S: Paris}\\ \text{T: 1930-07-04}\\ \text{A: Simone de B.}\\ \text{R: J.-P. Sartre}\\ \text{prn: 623}\end{bmatrix}$$

Here, toi is pointing at the R value J.-P., moi is pointing at the A value Simone, yesterday is pointing at the T value 1930-07-04, and the sem attribute of the verb has the value past from the hear mode analysis of the surface.

As an example without any indexicals consider Simone producing the following utterance addressed to J.-P., using her STAR-0 content 1.5:

*3.5. STAR-1 content without indexicals*

Fido barked.$^{\mathrm{STAR-1}}$

For the hearer J.-P., the interpretation of this content requires adjusting Simone's STAR-1 speak mode perspective to J.-P.'s STAR-2 hear mode perspective. This is based on the following STAR-2.2 inference:

*3.6. STAR-2.2 inference for content without indexicals*

$$\begin{bmatrix}\text{verb: }\alpha\\ \text{prn: K}\end{bmatrix}\begin{bmatrix}\text{S: L}\\ \text{T: D}\\ \text{A: N}\\ \text{R: O}\\ \text{prn: K}\end{bmatrix}\Rightarrow\begin{bmatrix}\text{verb: }\alpha\\ \text{prn: K}\end{bmatrix}\begin{bmatrix}\text{S: L}\\ \text{T: D}\\ \text{A: O}\\ \text{R: N}\\ \text{prn: K}\end{bmatrix}$$

J.-P. assigns Simone's STAR-1 to the input by inverting the A and R values of his STAR-2, coding J.-P.'s perspective, with the following result:

*3.7. STAR-2 content* Fido barked.

$$\begin{bmatrix}\text{noun: Fido}\\ \text{fnc: bark}\\ \text{prn: 572}\end{bmatrix}\begin{bmatrix}\text{verb: bark}\\ \text{arg: Fido}\\ \text{sem: past}\\ \text{prn: 572}\end{bmatrix}\begin{bmatrix}\text{S: Paris}\\ \text{T: 1930-07-03}\\ \text{A: J.-P. Sartre}\\ \text{R: Simone de. B}\\ \text{prn: 572}\end{bmatrix}$$

The properties of STAR-2 contents resulting from STAR-1 contents transmitted in face to face communication may be summarized as follows:

[8] Special cases are phone conversations, which require the hearer to recompute the speaker's S(pace) value; when talking across time zones, the speaker's T(ime) value must be recomputed as well.

*3.8. Operations of STAR-2 inferences*

1. The S value of the STAR-1 in the input (matching the antecedent) equals the S value of the STAR-2 in the output (derived by the consequent).
2. The T value of the STAR-1 in the input equals the T value of the STAR-2 in the output.
3. The A value of the STAR-1 in the input equals the R value of the STAR-2 in the output.
4. The R value of the STAR-1 in the input equals the A value of the STAR-2 in the output.
5. The prn value of the input equals the prn value of the output.

These properties hold specifically for STAR-2 contents. For example, in STAR-1 contents the author equals the A value, and not the R value.

The derivation of STAR-2 contents does not interfere with the cycle of natural language communication because it applies after the hear mode derivation and before storage in the Word Bank.

## 4. Dialogue with a WH Question and Its Answer

The statement dialogue analyzed in Sects. 1–3 is based on (1) the speaker producing and (2) the hearer interpreting a declarative sentence. A question–answer dialogue, in contrast, is based on 1. the questioner producing an interrogative, 2. the answerer interpreting the interrogative, 3. the answerer producing an answer, and 4. the questioner interpreting the answer.

Preceding these four steps, however, there is the emergence of the question *content*, called step 0. For example, having digested J.-P.'s remark 2.1, Simone searches her recent memory for connected letter, write, and J.-P. proplets, and realizes that she hasn't yet received the letter. This creates a certain kind of imbalance in her mind, commonly known as curiosity. As a means to regain her equilibrium, the following question content emerges in Simone's mind:

*4.1. Non-language content in the interrogative mood*

What did you write?$^{\mathrm{STAR}-0}$

In analogy to 1.1–1.4, the content and its anchor may be represented as the following set of proplets:

*4.2. Anchored STAR-0 content of WH interrogative*

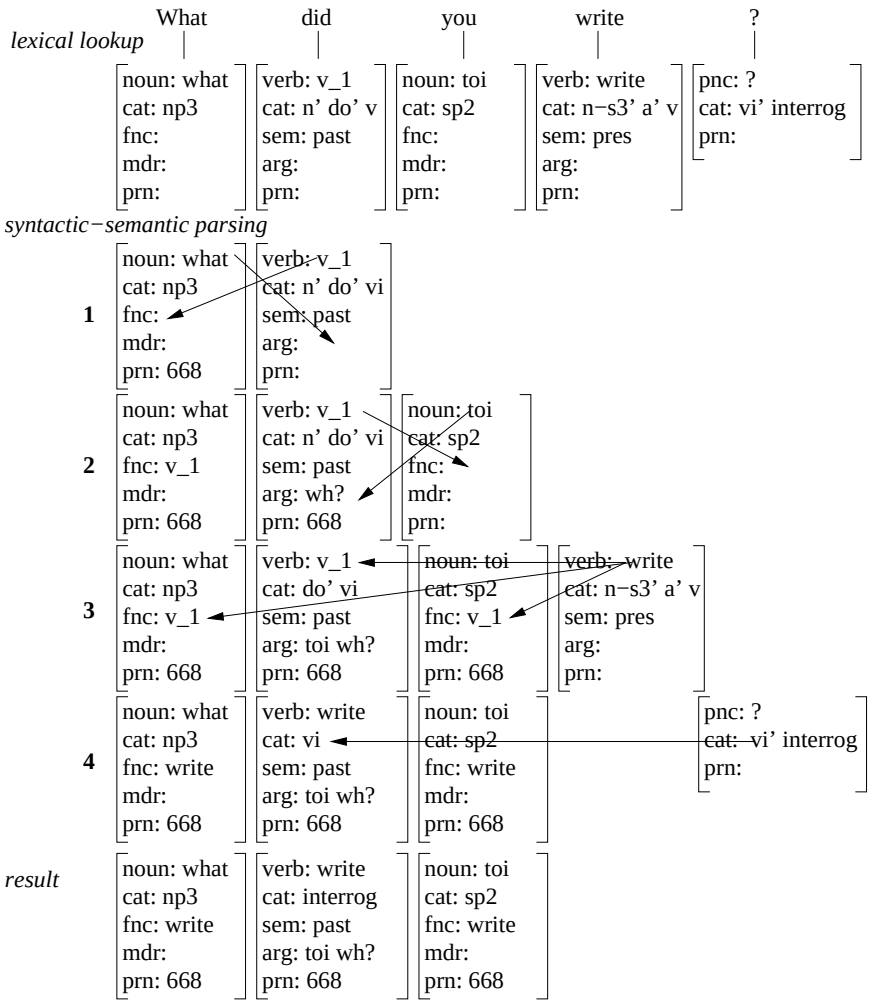
| | | | |
|---|---|---|---|
| noun: toi | verb: write | noun: wh? | S: Paris |
| fnc: write | cat: interrog | fnc: write | T: 1930-07-04 |
| prn: 625 | sem: past | prn: 625 | A: Simone de B. |
| | arg: toi wh? | | R: J.-P. Sartre |
| | prn: 625 | | prn: 625 |

As in 1.4, the connection between the STAR and the content is established by a common prn value, here 625. The indexical toi points at the R value of the STAR-0.

Given that there is no significant time difference between the formation of the content and its use for language production, there is no need to derive a speaker perspective on the content (in contrast to the transition from 1.1 to 2.1). Instead, Simone proceeds to realize the surface in 4.1 by using 4.2 as a STAR-1 content.

Now it is J.-P.'s turn to interpret the incoming surface (presented in English):

*4.3. Answerer as hearer parsing 4.1*




The result of this strictly time-linear, surface compositional derivation is a content which represents the perspective of the speaker Simone – except for the prn value, here 668, which is assigned by the hearer J.-P.

For understanding, the answerer J.-P. must change Simone's speak mode perspective into his own hear mode perspective by transforming the content Toi wrote what?[9] of Simone's question into Moi wrote what?, based on the following STAR-2.3 inference:

*4.4. STAR-2.3 inference for deriving hearer perspective*

$$\begin{bmatrix}\text{noun: toi}\\ \text{fnc: } \alpha\\ \text{prn: K}\end{bmatrix}\ \begin{bmatrix}\text{verb: } \alpha\\ \text{cat: interrog}\\ \text{arg: \{ X toi wh?\}}\\ \text{prn: K}\end{bmatrix}\ \begin{bmatrix}\text{noun: wh?}\\ \text{fnc: } \alpha\\ \text{prn: K}\end{bmatrix}\ \begin{bmatrix}\text{S: L}\\ \text{T: D}\\ \text{A: N}\\ \text{R: O}\\ \text{prn: K}\end{bmatrix} \Rightarrow$$

$$\begin{bmatrix}\text{noun: moi}\\ \text{fnc: } \alpha\\ \text{prn: K}\end{bmatrix}\ \begin{bmatrix}\text{verb: } \alpha\\ \text{cat: interrog}\\ \text{arg: \{ X moi wh?\}}\\ \text{prn: K}\end{bmatrix}\ \begin{bmatrix}\text{noun: wh?}\\ \text{fnc: } \alpha\\ \text{prn: K}\end{bmatrix}\ \begin{bmatrix}\text{S: L}\\ \text{T: D}\\ \text{A: O}\\ \text{R: N}\\ \text{prn: K}\end{bmatrix}$$

This STAR-2 inference complies with 3.8. Applying it to (i) the result of the hear mode derivation 4.3 and (ii) J.-P.'s current STAR-2 produces the following anchored content:

*4.5. Result of applying the STAR-2.3 inference to 4.3*

$$\begin{bmatrix}\text{noun: moi}\\ \text{fnc: write}\\ \text{prn: 668}\end{bmatrix}\ \begin{bmatrix}\text{verb: write}\\ \text{cat: interrog}\\ \text{sem: past}\\ \text{arg: moi wh?}\\ \text{prn: 668}\end{bmatrix}\ \begin{bmatrix}\text{noun: wh?}\\ \text{fnc: write}\\ \text{prn: 668}\end{bmatrix}\ \begin{bmatrix}\text{S: Paris}\\ \text{T: 1930-07-04}\\ \text{A: J.-P. Sartre}\\ \text{R: Simone de B.}\\ \text{prn: 668}\end{bmatrix}$$

At this point, the answerer J.-P. understands Simone's question. This has the effect of passing Simone's original imbalance (curiosity) successfully on to J.-P. as the hearer. To re-establish his equilibrium, J.-P. searches his recent memory for connected letter, write, and Simone proplets. When he finds the answer, J.-P. uses the speak mode to reply as follows (in French):

*4.6. Answerer as speaker*

A little poem.$^{\text{STAR}-1}$

The content underlying this answer has the following proplet representation:

*4.7. Answer to a WH question as a set of STAR-0 proplets*

$$\begin{bmatrix}\text{noun: poem}\\ \text{sem: indef sg}\\ \text{mdr: little}\\ \text{prn: 655}\end{bmatrix}\ \begin{bmatrix}\text{adj: little}\\ \text{mdd: poem}\\ \text{prn: 655}\end{bmatrix}\ \begin{bmatrix}\text{S: Paris}\\ \text{T: 1930-07-03}\\ \text{A: J.-P. Sartre}\\ \text{R: Simone}\\ \text{prn: 655}\end{bmatrix}$$

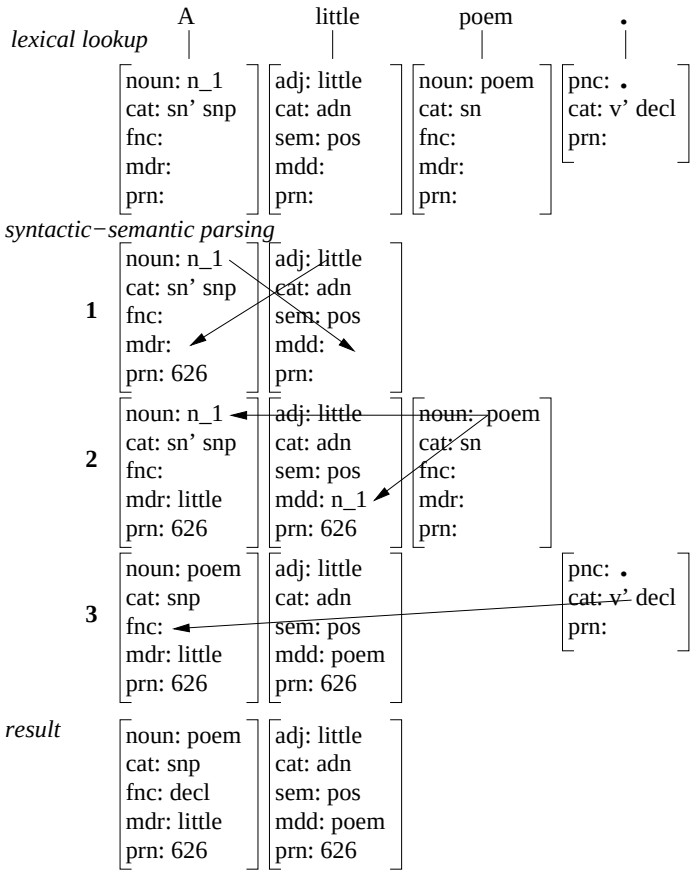
A pertinent answer must *precede* the question at the level of content in the mind of the answerer.[10] It is only when the answer is realized in language that it follows the question, for answerer and questioner alike.

The final turn of a question-answer sequence is the questioner in the hear mode. In our example, Simone as the hearer parses J.-P.'s answer as follows:

[9] The result of a hear mode derivation is a *set* of proplets, i.e., order-free. In other words, Toi wrote what? and What wrote toi? are equivalent.

[10] As reflected by the prn values 668 of the question 4.5 and 655 of the answer 4.7.

*4.8. Questioner as hearer parsing 4.6*




On the one hand, the answer to a WH question is declarative in nature, as indicated by the full stop. On the other hand, it is missing a verb. To characterize the result of the above derivation as a WH answer, we propose to copy the value decl of the full stop into the fnc slot of the noun, and to use the [fnc: decl] combination as a marker for WH answers interpreted as STAR-2 content.

While balance is re-established for the answerer when uttering the answer (cf. 4.6), the questioner must not only interpret the answer, as in 4.8, but combine the WH question and the answer into one declarative content. Derived by the following STAR-2 inference, the resulting content has a new prn value:

*4.9. STAR-2.4 inference connecting WH interrogative with answer*

$$\begin{bmatrix}\text{verb: } \alpha\\ \text{cat: interrog}\\ \text{arg: \{ X toi wh?\}}\\ \text{prn: K}\end{bmatrix}\ \begin{bmatrix}\text{noun: wh?}\\ \text{fnc: } \alpha\\ \text{prn: K}\end{bmatrix}\ \begin{bmatrix}\text{S: L}\\ \text{T: D}\\ \text{A: N}\\ \text{R: O}\\ \text{prn: K}\end{bmatrix}\ +\ \begin{bmatrix}\text{noun: } \beta\\ \text{fnc: decl}\\ \text{mdr: } \gamma\\ \text{prn: K+M}\end{bmatrix}\ \begin{bmatrix}\text{adj: } \gamma\\ \text{mdd: } \beta\\ \text{prn: K+M}\end{bmatrix}\ \Rightarrow$$

$$\begin{bmatrix}\text{verb: } \alpha\\ \text{cat: decl}\\ \text{arg: \{ X toi } \beta\}\\ \text{prn: K+1}\end{bmatrix}\quad\begin{bmatrix}\text{noun: } \beta\\ \text{mdr: } \gamma\\ \text{fnc: } \alpha\\ \text{prn: K+M}\end{bmatrix}\quad\begin{bmatrix}\text{adj: } \gamma\\ \text{mdd: } \beta\\ \text{prn: K+M}\end{bmatrix}\quad\begin{bmatrix}\text{S: L}\\ \text{T: D}\\ \text{A: N}\\ \text{R: O}\\ \text{prn: K+1}\end{bmatrix}$$

The inference fills the wh-gap in the question by replacing the *wh?* pattern proplet with the noun of the answer, including an optional pattern proplet for an adnominal modifier. The cat value interrog in the input verb is changed to decl in the output. The func value decl of the input answer noun is changed to the core value of the verb in the output. The result of applying this inference to the inputs 4.2 and 4.7 is as follows:

*4.10. Questioner's STAR-2 content for regaining balance*

$$\begin{bmatrix}\text{noun: toi}\\ \text{fnc: write}\\ \text{prn: 625+2}\end{bmatrix}\quad\begin{bmatrix}\text{verb: write}\\ \text{cat: decl}\\ \text{sem: past}\\ \text{arg: toi poem}\\ \text{prn: 625+2}\end{bmatrix}\quad\begin{bmatrix}\text{noun: poem}\\ \text{fnc: write}\\ \text{mdr: little}\\ \text{prn: 625+2}\end{bmatrix}\quad\begin{bmatrix}\text{adj: little}\\ \text{mdd: poem}\\ \text{prn: 625+2}\end{bmatrix}\quad\begin{bmatrix}\text{S: Paris}\\ \text{T: 1930-07-04}\\ \text{A: Simone de B.}\\ \text{R: J.-P. Sartre}\\ \text{prn: 625+2}\end{bmatrix}$$

The input prn value 625 is incremented by 2 because between Simone's production of the question content 4.2 and the content of 4.10 there is Simone's interpretation of J.-P.'s answer, as shown in 4.8.

## 5. Yes/No Question and Answer Dialogue

WH questions may request noun values, as in What did you write?, or adjective values, as in Why did you go? (cause), Where did you stay? (location), How did you sleep? (manner), or When did you leave? (time). They all conform to the time-linear structure of question-answer sequences (cf. 7.4), and their DBS analysis closely resembles that shown in the previous section for a WH question with a noun answer.

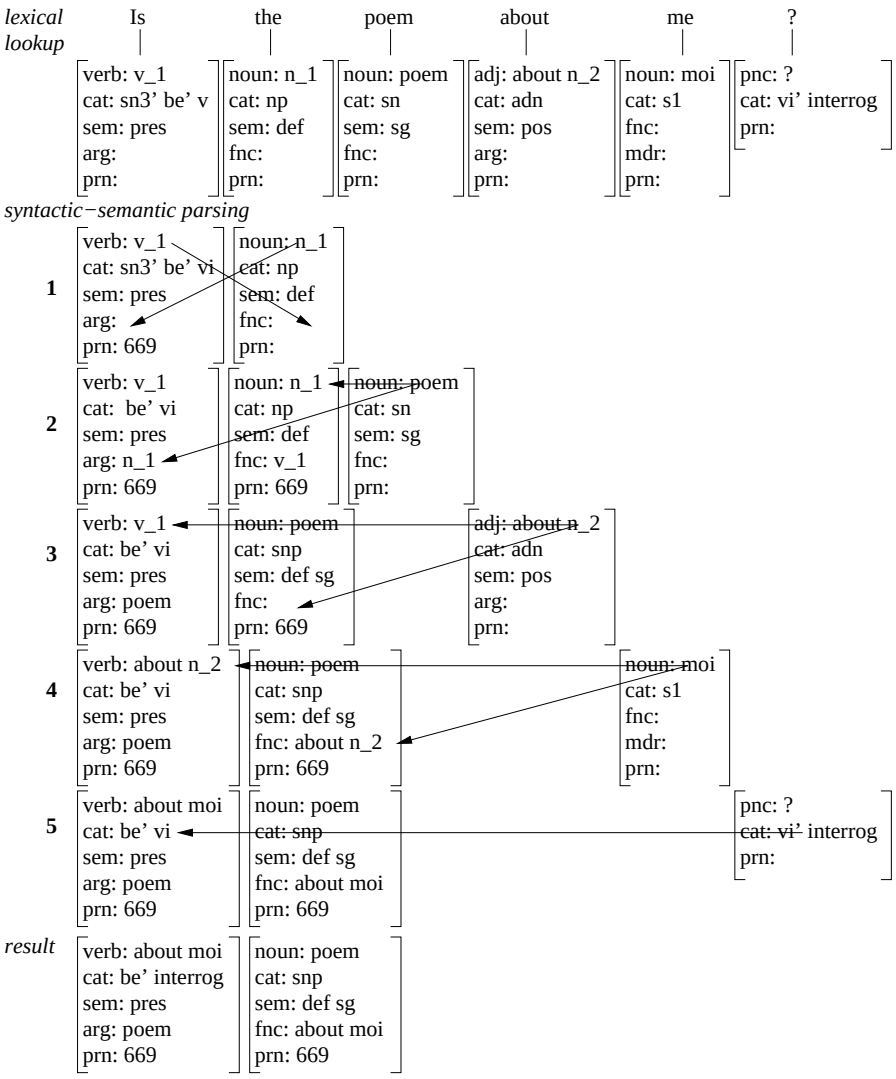
Yes/no questions conform to the same time-linear structure, but request a choice between only two values, namely yes and no. For example, after J.-P.'s answer A little poem., Simone's curiosity is not yet completely satisfied. As a potential countermeasure, the following non-language STAR-0 content emerges in her mind:

*5.1. STAR-0 content underlying language countermeasure*

Is the poem about me?$^{\text{STAR}-0}$

As in 4.1 and 4.2, this content is used by Simone as a STAR-1 content and realized as a surface (in French). From this surface, presented in English for convenience, the answerer J.-P. derives the following content:

*5.2. Answerer as hearer parsing a yes/no interrogative*




The result codes the perspective of the questioner Simone as speaker, except for the prn value, here 669, which is assigned by the answerer J.-P. as hearer.

Before storage in J.-P.'s Word Bank, Simone's speaker perspective coded as poem is about *moi*? must be revised into the perspective of the answerer as hearer, coded as poem is about *toi*?. The latter is represented as the following set of proplets:

*5.3. Answerer as hearer: revised perspective of 5.2*

| noun: poem | verb: about toi | S: Paris |
|---|---|---|
| cat: snp | cat: be' interrog | T: 1930-07-04 |
| sem: indef sg | sem: pres | A: J.-P. Sartre |
| fnc: about toi | arg: poem | R: Simone de B. |
| prn: 669 | prn: 669 | prn: 669 |

The revision of perspective, i.e., the change of moi into toi and the concomitant exchanges of the A and R values in the STAR-2, is based on a STAR-2 inference like 4.4.

At this point, J.-P. understands Simone's question and experiences an imbalance similar to the one which caused Simone to ask the question in the first place. To re-establish his homeostasis, J.-P. replaces the prn value 669 with a variable, e.g., K. This turns the revised STAR-2 content 5.3 into a schema which allows J.-P. to search his recent memory for a matching content.

A successful retrieval triggers a positive answer in J.-P.'s mind and switches the answerer from a hearer to a speaker. After stoking his pipe, J.-P. replies:

*5.4. Answerer J.-P. as speaker*

Yes.$^{\mathrm{STAR-1}}$

With this utterance, the answerer regains his equilibrium, but Simone must still do a hear mode derivation (questioner as hearer) and combine the result with the anchored content 5.1 as a STAR-1 content, represented as a set of proplets. This is based on a STAR-2 inference like 4.9; it replaces the cat value interrog of the verb with decl and assigns a new prn value.

## 6. Request and Fulfillment Dialogue

The third kind of basic dialogue besides statement and question dialogues are request dialogues. For example, Simone notes that her cigarette is about to be finished. Her need to dispose of the stub brings forth a slight imbalance, causing the following STAR-0 content to emerge as a countermeasure:

*6.1. Anchored non-language request content*

(Please)[11] pass the ashtray! $^{\mathrm{STAR-0}}$

The STAR-0 content 6.1 is represented as the following set of proplets:

*6.2. Request STAR-0 content as a set of proplets*

| | | |
|---|---|---|
| verb: pass | noun: ashtray | S: Paris |
| cat: impv | cat: snp | T: 1930-07-04 |
| sem: pres | sem: def sg | A: Simone de B. |
| arg: # ashtray | fnc: pass | R: J.-P. Sartre |
| prn: 630 | prn: 630 | prn: 630 |

The requestor equals the A value Simone and the requestee the R value J.-P. The sentential mood is shown as the verb's cat value impv, for imperative.

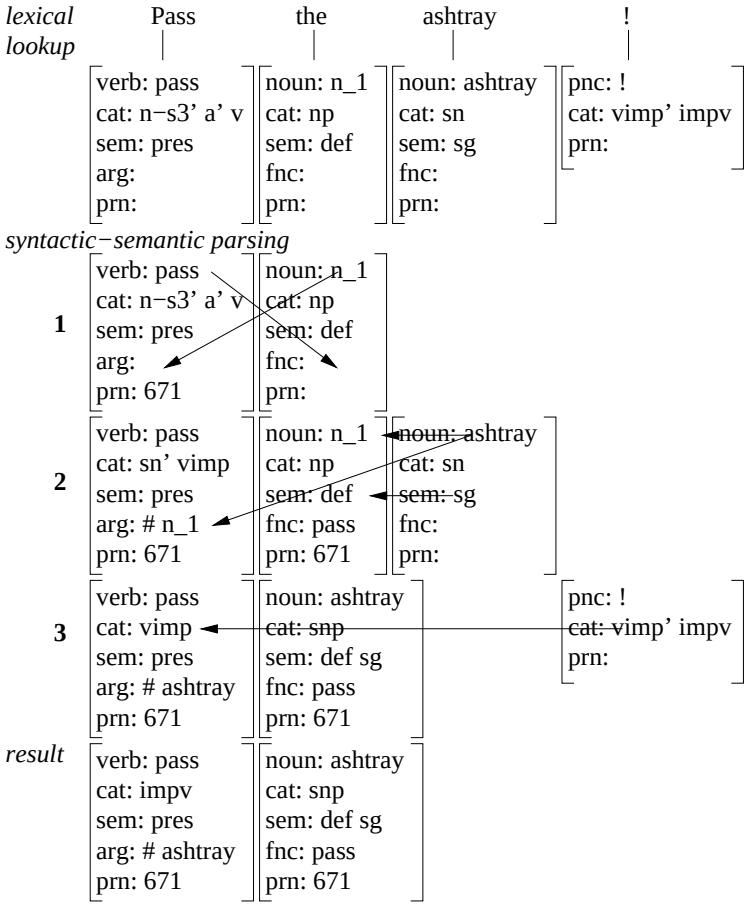
After a long last drag on her cigarette, Simone produces the surface in 6.1 based on the proplet set 6.2. The production of this content as a surface constitutes step 1 of the

[11] For simplicity, we omit the analysis of please. In terms of functor-argument structure, it may be treated as an adverbial modifier. Its pragmatic role is to indicate a polite attitude towards the hearer, similar to the use of vous instead of toi.

request-fulfillment sequence. Given that there is no significant time difference between the formation of the content and its use for language production, there is no need to derive a separate speaker perspective on the content. In other words, Simone may reuse the STAR-0 of 6.2 as the STAR-1 of her utterance.

In the next step (i.e., step 2, requestee as the hearer), J.-P. parses the surface in 6.1 as follows:

*6.3. Requestee as hearer parsing* Pass the ashtray!




The lexical analysis of pass is that of the standard unmarked present tense form of a verb.[12]

[12]The main sentential moods in natural language are the declarative, the interrogative, and the imperative. These sentential moods must be distinguished from the verbal moods, called the indicative, the subjunctive, and the imperative in grammars for English. Thus the term "imperative" has been used for both the sentential and the verbal mood.

In some languages the verbal moods are realized as special forms of the verbal morphology, with dedicated uses in the associated sentential moods. Classical Latin, for example, has separate word forms for the verb in the imperative mood, differentiated as to whether the requestee is a singular individual (curre, *run* impv. sing.) or a plural group (currete, *run* impv. pl.).

The conversion of the lexical cat value n-s3' a' v to sn' vimp (cf. line 2) is accomplished by the LA-hear rule which combines a sentence-initial finite verb with a noun. The result of this hear mode derivation equals the content 6.2 of the requestor as speaker, except for the prn value and a new STAR-2 as shown below:

*6.4. Request STAR-2 content as a set of proplets*

| | | |
|---|---|---|
| verb: pass | noun: ashtray | S: Paris |
| cat: impv | cat: snp | T: 1930-07-04 |
| sem: pres | sem: def sg | A: J.-P. Sartre |
| arg: # ashtray | fnc: pass | R: Simone de B. |
| prn: 671 | prn: 671 | prn: 671 |

Here the conversion from Simone's perspective as the requestor to J.-P.'s perspective as the requestee is limited to exchanging the A and R values in the STAR-1 (= STAR-0) of 6.2 as compared to the STAR-2 of 6.4. This has an effect similar to going from *toi* pass ashtray to *moi* pass ashtray, though the imperative content has no explicit subject, and consequently no indexical subject.

At this point, J.-P. understands the request: the slight imbalance experienced by Simone has been successfully passed on to him by means of natural language. As step 3 of a time-linear request sequence, the requestee must take the requested action in order to be cooperative. This may be a non-language action, as responding to Open the window!, or a language action, as responding to Tell me more about your mother! (Weizenbaum 1965).

In our example, the requestee J.-P. has been asked to perform a non-language action. Therefore, he is looking around for the means to realize his blue-print for action, which may be paraphrased as *Moi* pass ashtray. He recognizes the ashtray on the restaurant table and initiates a manipulation sequence which moves the ashtray over to Simone. This results in J.-P. regaining his equilibrium.

The final step 4 is the requestor recognizing the fulfillment of the request by the requestee. In our case, Simone puts out her cigarette in the ashtray. This results in her regaining her balance and closes the sequence.

In summary, the main difference between the time-linear sequence of a question and a request dialogue is that steps 3 and 4 in an question dialogue are realized as language action, while the corresponding steps in a request dialogue may be either language or non-language action. However, because all essential dialogue operations, especially the adjustments of perspective, are performed at the level of content, DBS can handle request dialogues just as well as question dialogues.

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English, in contrast, uses the unmarked form of the verb's present tense for constructing the imperative as a sentential mood. Thus, just as there is no separate verbal form for the infinitive, there is no separate verbal form for the imperative. Instead, the imperative as a sentential mood is built as a special syntactic-semantic construction, characterized by word order, intonation/interpunctuation, and the absence of a subject, tense, and verbal mood.

## 7. Conclusion

This paper analyzes dialogue as a sequence of elementary dialogues, using as example the following fictional conversation between Jean-Paul Sartre and Simone de Beauvoir in the Café de Flore on 1930-07-04:

*7.1. Sequence of elementary dialogue sequences analyzed in this paper*

| | | |
|---|---|---|
| J.-P. Sartre: | I wrote you a letter yesterday. | (statement, Sect. 1–3) |
| S. de Beauvoir: | What did you write? | (WH question, Sect. 4) |
| J.-P. Sartre: | A little poem. | (WH answer, Sect. 4) |
| S. de Beauvoir: | Is the poem about me? | (Yes/No question, Sect. 5) |
| J.-P. Sartre : | Yes. | (Yes/No answer, Sect. 5) |
| S. de Beauvoir: | (Please) pass the ashtray! | (request, Sect. 6) |
| J.-P. Sartre: | fullfils request | (fullfilment, Sect. 6) |

The elementary dialogues consist each of a characteristic sequence of turns which involve the following perspective conversions:

*7.2. Perspective conversions in time-linear sequences of elementary dialogues*

1. Statement Dialogue
   STAR-0: emergence of a non-language content in agent A (Sect. 1)
   STAR-1: production of a statement by agent A as the speaker (Sect. 2)
   STAR-2: interpretation of the statement by agent B as the hearer (Sect. 3)
2. Question Dialogue (Sect. 4 for WH and Sect.5 for Yes/No questions)
   STAR-0: emergence of a non-language content in agent A as the questioner
   STAR-1: production of a question by agent A as the speaker
   STAR-2: interpretation of the question by agent B as the hearer
   STAR-1: production of an answer by agent B as the speaker
   STAR-2: interpretation of the answer by agent A as the hearer
3. Request Dialogue (cf. Sect. 6)
   STAR-0: emergence of a non-language content in agent A as the requestor
   STAR-1: production of a request by agent A the speaker
   STAR-2: interpretation of the request by agent B as the hearer
   STAR-1: non-language or language fulfillment action by agent B as the requestee
   STAR-2: non-language or language fulfillment recognition by agent A as the requestor

Our analysis proceeds systematically from the perspective of the speaker to that of the hearer. The transition from one perspective to the next is described in terms of explicit STAR inferences. Part of the analysis is the interpretation of first and second person pronouns (indexicals), which differs for the speaker and the hearer. Our theory complements Schegloff's (2007) socio-linguistic analysis of many recorded and transcribed dialogues, based on the more abstract notions of "first," "second," "pre," and "post."

**Acknowledgments**

This paper benefitted from comments by Johannes Handl, Besim Kabashi, Thomas Proisl, and Carsten Weber, research and teaching associates at the Abteilung für Computer-Linguistik Uni Erlangen (CLUE).

**Bibliography**

Endsley, M. and D.J. Garland (eds.) (2000) *Situation Awareness and Measurement*, Mahwah, New Jersey: Lawrence Earlbaum Associates

Endsley, M., B. Bolte, and D. G. Jones (2003) *Designing for Situation Awareness*, London and New York: Taylor and Francis

FoCL'99 = Hausser, R. (1999) *Foundations of Computational Linguistics, Human–Computer Communication in Natural Language, 2nd ed. 2001*, Springer

Hausser, R. (2010a) "Inferencing in Database Semantics", *Information Modelling and Knowledge Bases XXII*, Kiyoki, Y., T. Tokuda, A. Heimbürger, H. Jaakkola and N. Yoshida (eds), Amsterdam: IOS Press

Hausser, R. (2010b) "Language Production Based on Autonomous Control - A Content-Addressable Memory for a Model of Cognition," in *Language and Information*, Vol. 11:5-31

Hausser, R. (2011) *Computational Linguistics and Talking Robots*, Springer

Montague, R. (1974) *Formal Philosophy*, New Haven: Yale U. Press

Schegloff, E. (2007) Sequence Organization in Interaction, New York: Cambridge Univ. Press

Weizenbaum, J. (1965) "ELIZA – A Computer Program for the Study of Natural Language Communications between Man and Machine," *Commun. ACM*, Vol. 9.1 (11).