THERE IS AS YET INSUFFICIENT DATA FOR A MEANINGFUL ANSWER[*]

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Abstract

Formal studies of discourse raise numerous interrogations on the nature and the definition of the way consecutive sentences combine with one another. The shift from discourse to dialogue brings forward even more specific issues. Dialogue acts are more intrinsically connected because of the dynamicity of the interaction. This article introduces a proof of concept of a formal compositional treatment of the relationship between consecutive utterances. Starting from neo-Davidsonian event semantics, we propose to use the *relative response set* as an intermediate set tool that allows us to define notions of question-answer correspondence, model the effect of clarification requests on previous utterances and compute semantic representations of dialogue interactions.

1 Introduction

Dialogue is governed by both implicit and explicit, quite complex rules of interaction. It allows us, dynamically, to share an important informational content by using relatively simple utterances. While we do participate in dialogues, we do not fully understand the underlying mechanisms allowing the combination of dialogue acts: what makes dialogue acts compatible, coherent. In this article, we present an analysis of dialogue interactions. First, we focus on questions and answers which are at the root of the difference between dialogue and discourse. What is a question? What is an answer? What makes an answer satisfactory? How to define question/answer relationship in a precise, computational way?

It is relatively easy to define *questions*, as dialogue acts, syntactically, at least as utterances marked with one of the question marks/a rising intonation/a question particle/a question word. Semantically, a question is a sentence or phrase used to find out information[1]. Defining what constitutes an *answer* and how it fulfils its answering role is way more complex. Sometimes, the answer to a question is an entity, one element of information. Sometimes, the answer defines or shapes a set of entities or elements of information, but is not sufficient to choose an element of this set. Still, we answer questions daily, and there is an extensive literature about identifying answers to questions (Traum, 1994; Ginzburg and Sag, 2000; Rao et al., 2016; Lai et al., 2019; Yao et al., 2013). After a long period of expert systems, recent developments are largely rooted in neural networks and word embeddings (Mikolov et al., 2013; Österlund et al., 2015).

The later approaches integrate little or no linguistic descriptions of dialogue itself. One of the main reasons for this is that formal or computational models of dialogue are scarce. We went through the literature on questions and answers throughout the different existing formalisms based on formal semantics (AMR (Banarescu et al., 2013), MRS (Copestake et al., 2005), *etc.*), see section 2. The developments of *Type Theory with Records* (Cooper and Ginzburg, 2015) give us one of the most advanced current models for dialogue. This formal approach roots its representation in complex type theory.

Linguistic studies of dialogue based on real-life data show evidence of a frequently appearing type of utterance: *clarification request* (CR). They are designed to help the dialogue continue even when there are lapses in the process of exchanging conversational content. (Purver, 2004) defines clarification requests as "device[s] allowing a user to ask

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[*] `https://en.wikipedia.org/wiki/The_Last_Question`

[1] Definition based on `https://dictionary.cambridge.org/dictionary/english/question`, visited on May 8th 2020.

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about some feature (e.g. the meaning or form) of an utterance, or part thereof". Clarification requests can be used for different metacommunicational reasons (Ginzburg, 2012):

- To ask for a repetition or to request clausal confirmation: a confirmation question concerning the semantic contribution of a particular constituent within the entire clausal content of the utterance;
- To confirm intended content: query on a content a speaker intends to associate with a given (sub-)utterance, independently of the remaining content of the clause being resolved or not;
- To correct the other speaker.

We want to account for clarification request phenomena in dialogue in a computational (logic, compositional, dynamic) way. In particular, we are interested in the action of clarification requests on the previous utterance. Corpus observations conducted on the British National Corpus (BNC, see (Burnard, 2000)) list several types of clarification requests (Purver et al., 2003), see table 2. Computationally speaking, how different is the action of those different types of clarification requests?

Computational approaches of dialogue as opposed to ones for discourse run into very specific difficulties. We find particular phenomena such as sequences of questions, simultaneous presence of an information and its opposite, along with usage of Non-Sentential Utterances. Beyond mechanical aspects of dialogue, one needs to consider meta-levels: links with argumentation (argument-mining, topoi studies), see for example (Breitholtz, 2014), along with simultaneous dialogues management (Asher et al., 2016a).

Following the neo-Davidsonian event semantics representation of declarative sentences introduced by (Champollion, 2011) and the semantic representation of questions introduced by (Boritchev and Amblard, 2019a), we define the *relevant response set* with respect to a question Q, $\mathscr{R}_Q$. This set constitutes an intermediate computational step for dialogue representation.

We use the taxonomy of answer types introduced in (Ginzburg, 2012) and $\mathscr{R}_Q$ to formally characterize different types of answers and interpret the capacity of answerhood of a given utterance to a given question, see section 5. To do so, we adapt the modern type theoretical definitions given in (Ginzburg, 2012) to our montagovian-like approach. We then extend our model using the taxonomy of clarification requests introduced in (Purver, 2004) in order to model articulation of utterances in dialogue. We use examples from the DinG (*Dialogue in Games*) corpus[2], under construction (Boritchev and Amblard, 2018), to test our formal approach. This corpus is composed of transcriptions of recordings of people playing the *Catan* board game, in French. The participants are designated by the colour of their tokens: **Red**, **White**, **Yellow**, **Blue**. This game is also used in the STAC (*Strategic Conversation*) corpus (Asher et al., 2016b), which gathers logs of virtual games in English. (Hunter et al., 2018) proposes a detailed study of the written dialogue interactions based on (Asher et al., 2003). One of the future developments of DinG lies in testing the proposed logical underpinnings at a multi-lingual and multi-modal level.

2 Dialogue Models

There is an extensive litterature studying dialogue, (Grice, 1975), (Austin, 1975), (Freed, 1994), just to cite a few examples. These approaches mostly come from linguistics and philosophy. The computational aspect of dialogue is largely discussed in applications such as chatbot programming or information retrieval, where the main focus is semantic content research. The computational linguistics point of view, that we defend, lacks of an operational, computational description of dialogue through the study of dialogue acts and the way they combine, rooted in real-life data. The work we present in this article follows the tradition of formal semantics account of interrogatives as set by (Groenendijk et al., 1997), (Ginzburg, 1995a,b) and the structured meaning approach as presented in (Krifka, 2001). We work on real-life data that comes from the DinG corpus because it gives us both straightforward and complex examples, while being quite restrained in topic and vocabulary, which simplifies the computations.

Among formal, computational linguistics approaches, one can find Abstract Minimal Representation (AMR). In this formalism, questions are marked with a label: `amr-unknown`. Polar questions are represented as declarative sentences with an `amr-unknown` in the `:polarity` field, corresponding to the idea that one doesn't know the

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[2] `https://gitlab.inria.fr/amblard/ding` for data. Frequent updates to be expected.

truthfulness of the sentence[3]. AMR doesn't provide deep means of representation for quantifiers, which is not a problem if one wants mainly to represent what is going on in a dialogue, but constitutes one for representation based logical reasoning. On the linguistics side, there is no native way to represent clarification requests (CRs) because AMR wasn't specifically designed for dialogue.

Some works from Segmented Discourse Representation Theory (SDRT) (Asher et al., 2003) also approach dialogue from a perspective similar to the one for discourse semantics. (Amblard et al., 2015) presents an extension of SDRT for dialogue analysis that introduces a horizontal relation for question-answer relationship. (Xuereb and Caelen, 2004) uses SDRT for Human-Machine interaction tasks. These are simplifications of a theory that is not dedicated to dialogue. Though particular properties can be put forward in this way, it doesn't present a native way to model questions and answers.

Minimal Recursion Semantics (MRS) is a framework with complex descriptions for representation and reasoning (Egg, 1998; Yao and Zhang, 2010). It contains numerous rules with elaborate articulations. MRS allows question representation but does not natively account for the partial aspects of answers, that are prevalent in dialogue. Non-Sentential Utterances (NSU) constitute around 10% in English speaking corpora such as BNC (Fernández et al., 2007). NSUs can appear under various forms and for different types of illocutionary use. (Schlangen and Lascarides, 2003) presents an MRS and SDRT based treatment of NSUs. The approach presented in our article takes care of two types of NSUs: short answers (*"yes"*, *"no"*, *"stone"*, etc.) and CRs. We plan on developing our approach by adapting ideas from (Schlangen, 2003).

DIT++ (Bunt, 2009) is a semantics-inspired framework for human dialogue annotation and analysis, that integrates relations coming from SDRT. This framework provides a very detailed and precise classification of questions and answers. Clarification requests can be analysed in this framework, though they are dissolved among the other dialogue acts (not a category on their own). DIT++ is not a computational model, it is not designed for reasoning on the representations. Yet, any computational model can thrive on annotations provided by this framework. In particular, the representations presented in our article can and should be built using DIT++ annotation schema.

(Cooper and Ginzburg, 2015) presents KoS, an approach deeply rooted in linguistics and based on Type Theory with Records. It is oriented towards dialogue management modeling and revolves around a context-centered view of the dialogue. Each speech turn is viewed as a function modifying the interlocutor's context, as in dynamic semantics. Representations of dialogues in KoS mostly describe situations, in order to produce a big picture of the interaction. However, there is no use of syntax-semantics interface in KoS, thus it isn't easy to set a compositional construction of a model for utterances starting from representations of individual components of the sentences. Still, KoS accounts for different types of dialogue acts and for NSUs.

3 The Relevant Response Set

Sentences can be represented in a logical, compositional and dynamic way (Cresswell, 1976). We rely on these notions to grow and define the representation of utterances and the concept of *relevant response set*. We assume that the latter helps to materialize the implicit mechanisms going on in dialogue, in particular for notions of compatibility between two successive utterances.

First, we introduce the representations that we use. As we do not have the space here to broadly present and explain all the theories, we will use examples in addition to pointers to extensive references.

Our goal is to produce semantic representation (SR) of utterances. Several strategies can be used to achieve this; our approach is part of a compositional vision of treatments. As we want to keep the process generic, we follow a neo-Davidsonian representation of semantics (Maienborn, 2011). (Boritchev and Amblard, 2019a) offers a process to compute compositional representations of questions by using neo-Davidsonian event semantics formalisms (Champollion, 2011).

To each declarative sentence S we associate the first order logic formula $[\![S]\!]$, following (Champollion, 2015). This gives us the possibility to compute the semantic representation (SR) of utterances which syntactically behave as declarative sentences: some of the assertions, some of the answers.

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[3] Source: `https://github.com/amrisi/amr-guidelines/blob/master/amr.md#questions` at 07.06.20.

A polar, or *yes/no*-question requests a confirmation or a denial of its informational content. Therefore, one can see it as a declarative sentence (with the same content) that will be either directly accepted or negated and then accepted, depending of whether the answer is *"Yes"* or *"No"*. We denote the declarative content of a polar question Q_p as $decl(Q_p)$.

Definition 1 (SR of a polar question) *Consider Q_p, a polar question. The* semantic representation of Q_p, *following (Boritchev and Amblard, 2019a), is the semantic representation of Q_p's declarative content:*

$$[\![Q_p]\!] = [\![decl(Q_p)]\!].$$

Example 1 *Polar question, DinG, SR of a polar question*

Red$_1$ *Quelqu'un veut m'échanger de l'argile ?*
Red$_1$ *"Does someone want to trade clay with me?"*

$$\begin{aligned}
&[\![\mathbf{Red}_1]\!]\\
&= [\![\textit{Does someone want to trade clay with me?}]\!]\\
&= [\![\textit{Someone wants to trade clay with me}]\!]\\
&= [\![\textit{Someone wants to trade clay with } \textbf{\textit{Red}}]\!]\\
&= \exists e.\exists x.\exists y.\ trade(e) \wedge Ag_1(e,x) \wedge Th(e,y)\\
&\quad \wedge clay(y) \wedge Ag_2(e,\mathbf{Red})
\end{aligned}$$

In this example, we identify an event `trade` that is built upon two agents and a theme. It is represented with a predicate[4].

The computation of the semantic representation is based on the syntax-semantic interface. Following (Champollion, 2011), we assume that the syntax-semantic interface we use is underpinned by the generative theory (Chomsky, 1999, 1995). Thus the parsing of a *wh*-question is derived from a first phase, the deep syntax, where the complements/arguments are in canonical positions.

Example 2 *Wh-question, DinG*

In this example, ***White*** *is talking specifically to* ***Red****.*

White$_1$ *Tu as combien de moutons ?*
White$_1$ *"How many sheep do you have?"*

For **White**$_1$, the considered intermediate state is *"You have how many sheep"*. This corresponds exactly to the structure needed to compute the semantic representation of the question. Then, an abstract variable is introduced, corresponding to the thematic role that is being interrogated. In **White**$_1$, this role is `Amount`. We denote $DeepS(S)$ the deep syntactic state of a sentence S.

Definition 2 (SR of a *wh*-question) *Consider Q_w a wh-question, where w is the thematic role corresponding to the wh-word appearing in the question. Let x be a free first order logic variable. Then the semantic representation of Q_w is the semantic representation of Q_w's deep syntactic view, where the variable corresponding to the thematic role w is x, and it is bound by λ. $[\![DeepS(Q_w)]\!]$ starts with λx and x appears in $DeepS(Q_w)$.*

$$[\![Q_w]\!] = [\![DeepS(Q_w)]\!].$$

See (Boritchev, 2017) for a correspondence between wh-words and thematic roles.

Following these definitions, example 2 gives us the following representation (see section 4 for details on the computation):

$$\begin{aligned}
&[\![\mathbf{White}_1]\!]\\
&= [\![\text{How many sheep do you have?}]\!]\\
&= [\![\text{Red has how many sheep}]\!]\\
&= \lambda x.\exists e.\exists z.have(e) \wedge Ag(e,\mathbf{Red}) \wedge player(\mathbf{Red})\\
&\quad \wedge Th(e,z) \wedge sheep(z) \wedge Amount(z,x)
\end{aligned}$$

Remark 1. The fact that the representation of a question still contains a λ-abstraction handles the querying part of the question. For discourse-oriented representations computations, this would be the sign of a malfunction of the syntax-semantics interface.

Remark 2. We consider that the question is about the variables in the order of their abstraction. The representation of $Q_{Ag,Th,Time,Location}$ = *"Who killed whom, when and where?"* starts with an abstraction on the variable to which the predicate representing the thematic role `Agent` is applied.

(Ginzburg, 2012) distinguishes 5 types of notions for the answers: (1) *simple answerhood*, (2) *aboutness*, (3) *strong exhaustive answer*, (4) *partially resolving answer*, and (5) *question/question relations* (answer to a question by a question). We propose to introduce an intermediate level of description between questions and answers. To be able to formally define what constitutes an

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[4] See (Babonnaud, 2019) for a discussion about choices of predicate ontologies.

answer to a question Q, we introduce the *relevant response set* $\mathscr{R}_Q$. It is the set of entities that fulfill the constraints introduced in the semantic representation of the question Q.

Definition 3 (Co-predicated variables)
Consider a first order logic formula F, a predicate p and two variables x and y. x and y are co-predicated *in P if $p(x, y)$ or $p(y, x)$ occur in F.*

Definition 4 (A question's relevant response set)
Consider Q a question. The relevant response set *w.r.t. Q, denoted $\mathcal{R}_Q$, is syntactically built from $\llbracket Q \rrbracket$ by restricting it to the quantifiers and predicates of Q applied to x, corresponding to the thematic role that is being interrogated, and its co-predicated variables in Q.*

Example 3 *Computation of $\mathscr{R}_{\mathbf{Red_1}}$ from $\llbracket \mathbf{Red_1} \rrbracket$ (example 1)*

$$\begin{aligned}
&\mathscr{R}_{\mathbf{Red_1}}\\
&= \textit{set of all entities satisfying } \llbracket \mathbf{Red_1} \rrbracket\textit{'s constraints}\\
&= \textit{set of all players that can take part in the}\\
&\quad \textit{trade event}\\
&=\{x \mid \exists e.\ trade(e) \wedge Ag_1(e, x) \wedge Ag_2(e, \mathbf{Red})\}\\
&=\lambda x.\exists e.\ trade(e) \wedge Ag_1(e, x) \wedge Ag_2(e, \mathbf{Red})
\end{aligned}$$

Remark 3. For the sake of simplicity, we do not take the modality conveyed by using the verb *to want* into account in this computation. There are several ways to process modality in discourse, see for example (Bybee and Fleischman, 1995; Capone, 1997; Van Ditmarsch et al., 2007).

The goal here is not to define an algorithm to build the representation, but to be able to infer $\mathscr{R}_Q$ from the representation of the question Q itself. $\mathscr{R}_{\mathbf{Red_1}}$ is built from the representation $\llbracket \mathbf{Red_1} \rrbracket$ using all the predicates concerning the queried variable (x) and all the predicates concerning the non-event variables in those predicates. The question-answer relationship is built around $\mathscr{R}$. Intuitively, this approach is close to a montagovian type-raising on the question-answer relationship. Now that we have defined how to build $\mathscr{R}_Q$ from Q, we can formally define the notion of *answer*. If we interpret $\mathscr{R}_Q$ as the representation of the answer's informational content, we also need to account for the answer's possible polarity, that varies.

Definition 5 (Answer)
An answer A to a question Q is a couple composed of a subset of $\mathscr{R}_Q$ and a polarity:

$$\mathcal{A} = (\mathscr{R}', p), \mathscr{R}' \subseteq \mathscr{R}_Q, p \in \{+, -\}$$

Where $+$ can be represented by $\lambda P.P$ and $-$ by $\lambda P.\neg P$, see (Groenendijk et al., 1997).

Remark 3. The case of interro-negative questions uses several levels of negation, thus an adaptation of our model is necessary, see section 5.1 for further details.

Example 4 *A possible answer to Red_1*
Consider the answer "Blue does!", uttered by ***Yellow****. Then:*

$$A = (\{\mathbf{Blue}\}, +).$$

Our observations of the effect clarification requests have on preceding utterances (see section 6) bring us to the definition of two functions. These functions account for the effects of CRs on $\mathscr{R}_Q$.

Definition 6 (Clarification function)
The clarification function `CF` *takes as arguments a λ-term L of neo-Davidsonian event semantics and two predicates p_1 and p_2, such that p_1 appears in L and the arity of p_1 and p_2 is the same.* `CF`*(L, p_1, p_2) is L where p_1 has been substituted by p_2.*

`CF` accounts for modifications of predicates inside an existing $\mathscr{R}_Q$. The next function, `CF+`, adds information inside an existing $\mathscr{R}_Q$.

Definition 7 (Additive clarification function)
The additive clarification function `CF+` *takes as arguments a λ-term L of neo-Davidsonian event semantics and one predicate, and the result of its application is the addition of the predicate in the L, under the scope of the λ.*

We use $\mathscr{R}_Q$, A, `CF` and `CF+` to model the articulation of utterances in dialogue. First, we present the way our model works with an extensive example.

4 The Model: an Example

The discussion in section 3 gives an overview of the semantic representation we want to compute. We focus on the compositional treatments that produce the representation. In the following, we compute the semantic representation of example 2.

We focus on a slightly modified version of the example with an explicit player, **Red**, as instead of the deictic 'you' we prefer to use a constant in the semantic representation. Another solution would be to use a free variable, but we prefer not to use them as we want to produce well-formed logical formulae. We claim that the representation of the question is equivalent to the one of the deep syntax. We consider both the syntax and thematic role: here, **Red** is the `Agent`, *"sheep"* the `Theme` and *"how_many"* the `Amount`.

$$\begin{aligned}
&\llbracket \text{How many sheep do you have?} \rrbracket \\
&= \llbracket \text{you have how many sheep} \rrbracket \\
&= \llbracket \textbf{Red} \text{ has how many sheep} \rrbracket \\
&= \llbracket \textbf{Red}\text{[ag] has how many[amount] sheep[th]} \rrbracket
\end{aligned}$$

Remark 3. 'How many' is treated as a multiword expression, following a simplified version of (Asher and Lascarides, 1998). The *wh*-word is considered as the syntactic determiner, and semantically expresses the quantity/amount.

The syntactic relations in the sentence can be represented with the tree of the figure 1. The nodes of the tree account for the semantic derivation and present the types of the intermediate computation steps. Leaves are either words of the sentence or thematic roles.

Here, we follow a simplification of the syntax-semantic interface for generative theory, (Chomsky, 1999), in the same perspective as (Champollion, 2015). For a developed presentation of the syntax-semantic interface for generative theory in montagovian view, see (Amblard, 2007).

Following the application order given by the syntactic tree, we compute the semantic representation of example 2.

$$\begin{aligned}
&= \llbracket \textbf{Red}\text{[ag] has how many[am] sheep}[th] \rrbracket \\
&= \llbracket (\textbf{Red } [agent]) \text{ (has (((how\_many } [amount]) \\
&\quad \text{sheep })[theme])) \rrbracket
\end{aligned}$$

Once we have the structure of the syntax-semantic interface, we explicitly have the functional application for our λ-terms. First, we need to discuss the semantic types.

We start from Montague's semantics based on simple type theory (Church, 1940), from which we inherit the elementary types e for *entities* and t for *truth values*, and the application $\langle \_, \_ \rangle$ (Cresswell, 1976).

Following (Champollion, 2011), we use v as the elementary type for *events*. Finally, we introduce a list of elementary types that are specific to semantic roles; here, we will consider the type n for *numerals*, corresponding to the semantic role $[amount]$.

In a montagovian tradition, a sentence is of type t: it corresponds to its truth value, as a sentence is either true or false. In neo-Davidsonian event semantics, a sentence is a quantification on an event, it is of type $\langle vt, t \rangle$, that we denote $\mathbb{S}_e$.

Consider the computation of the node marked ①. **Red** is a noun phrase (NP), that is classically of type $\langle et, t \rangle$, that we denote $\mathbb{NP}$. $[agent]$ is a thematic role, and following a neo-Davidsonian event semantics interpretation, it changes a noun phrase into a neo-Davidsonian event semantics noun phrase (NP$_e$).

Note that in that work the semantic of a $\mathbb{NP}$ does not include the event. We claim that the NP is semantically defined for itself and it is its inclusion in the sentence which need a variable which make the link in the formula. Here, $\llbracket \mathbf{Red} \rrbracket = \mathbf{Red}$ but the semantic representation of the $\mathbb{NP}$ contains $agent(e, \mathbf{Red})$ where e is the agent variable of the main verb. Note that in that case, we need to switch the functor/argument relation between the $\mathbb{VP}$ and the $\mathbb{NP}$.

The $\mathbb{NP}$ is of type $\langle \langle et, t \rangle, \langle \langle vt, t \rangle, \langle vt, t \rangle \rangle \rangle$, that we denote $\langle \mathbb{NP}, \mathbb{NP}_e \rangle$. Following (Champollion, 2015). The corresponding λ-terms are:

$$\begin{aligned}
\llbracket \mathbf{Red} \rrbracket &= \lambda P.P(\mathbf{Red}) \\
\llbracket [agent] \rrbracket &= \lambda Q.\lambda V.\lambda f.Q(\lambda x.V(\lambda e.[f(e) \\
&\qquad \wedge Ag(e, x)]))
\end{aligned}$$

It is important to notice that the latter term composes a previous term of the derivation with a thematic predicate. The challenge here is the unification of the event variable.

Then, the type of the verb is adapted to the fact that we are in a framework with events. Therefore, *has* is of type $\langle \mathbb{NP}_e, \langle \mathbb{NP}_e, \mathbb{S}_e \rangle \rangle$. Using these notations, we give the types of the constituents in table 1.

In a purely computational perspective, asking a question amounts to invert the functor/argument relationship to rise the questioned element to the surface. This idea gives us the type of $\llbracket how\_many \rrbracket$.

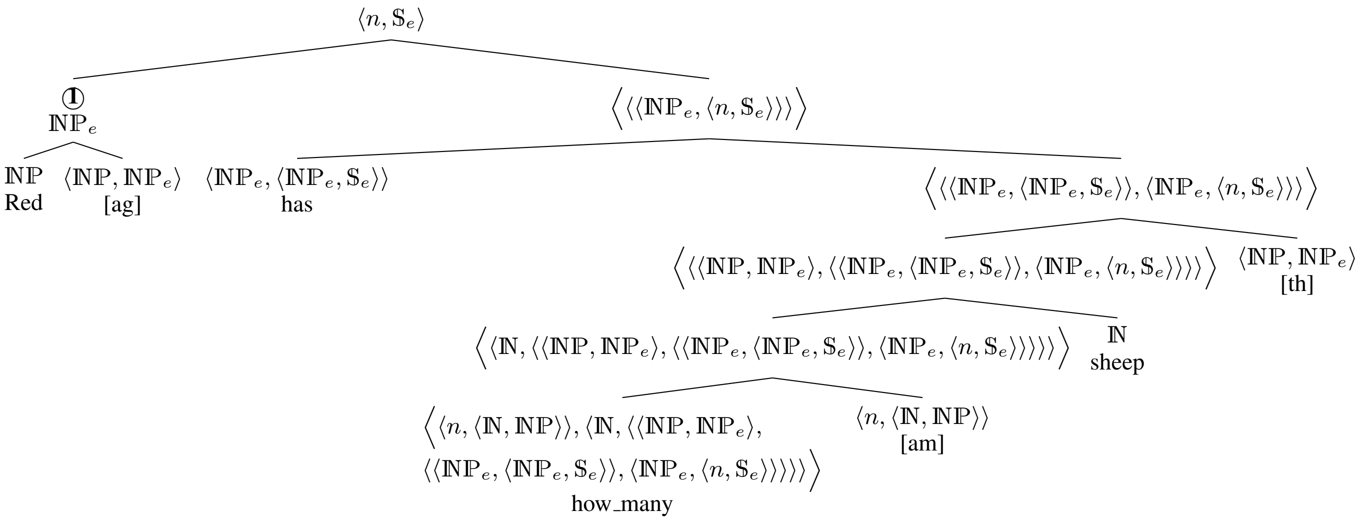

Figure 1: Representation of the syntactic relations

$\llbracket Red \rrbracket$	$\mathbb{NP}$
$\llbracket [agent] \rrbracket$	$\langle \mathbb{NP}, \mathbb{NP}_e \rangle$
$\llbracket has \rrbracket$	$\langle \mathbb{NP}_e, \langle \mathbb{NP}_e, \mathbb{S}_e \rangle \rangle$
$\llbracket how\_many \rrbracket$	$\Big\langle \langle n, \langle \mathbb{N}, \mathbb{NP} \rangle \rangle, \langle \mathbb{N}, \langle \langle \mathbb{NP}, \mathbb{NP}_e \rangle, \langle \langle \mathbb{NP}_e, \langle \mathbb{NP}_e, \mathbb{S}_e \rangle \rangle, \langle \mathbb{NP}_e, \langle n, \mathbb{S}_e \rangle \rangle \rangle \rangle \rangle \Big\rangle$
$\llbracket [amount] \rrbracket$	$\langle n, \langle \mathbb{N}, \mathbb{NP} \rangle \rangle$
$\llbracket sheep \rrbracket$	$\mathbb{N}$
$\llbracket [theme] \rrbracket$	$\langle \mathbb{NP}, \mathbb{NP}_e \rangle$

Table 1: Semantic types, simplified notation

Then, we have:

$$\llbracket [amount] \rrbracket = \lambda n.\lambda R.\lambda P.\exists x.(R(x) \wedge P(x) \\ \wedge\ Amount(x, n))$$

We note that here the type of $\llbracket how\_many \rrbracket$ is quite complex. The double type raising leads to a unique term around which the whole semantic representation of the sentence is build. An important remark is the fact that the term must be first combined with a term of type n, pushed at the end of the type with $\langle n, \mathbb{S}_e \rangle$, which is the type of a sentence where an n is missing.

This exactly corresponds to our idea to combine the different pieces of semantic representations into a single formula.

We propose a treatment of the example 2. The same treatment can be applied if the question is on the $\mathbb{NP}$ subject, but in that case, we have to rewrite the λ-term.

Another solution is to shift the focus from *"how_many"* to the thematic role itself, by deconstructing *"how_many"* and writing questioning versions of the thematic roles, that would be different from the declarative ones. We leave this discussion open for future works.

5 The Model: Case Studies

In this section, we illustrate how $\mathscr{R}_Q$ is used as an intermediate level of representation between questions and answers and how answers can be related to a question.(Ginzburg, 2012) introduces five answer types. We distinguish *simple answers* from the four others, that are more complex and are addressed in section 5.2.

5.1 Simple answers

A *simple answer* is a single-item utterance in a dialogue concerning either an instantiation of a question or the negation of such an instantiation.

Example 5 *Simple answer, DinG*[5]

Blue$_1$ *C'est quoi qui rapporte le plus de thune ?*
Blue$_1$ *"What brings in the most cash?"*

Yellow$_2$ *Le 6*
Yellow$_2$ *"The 6"*

The answer is unique (6). It is an instantiation of the problem *"Among the possible numbers on the dice, what is the one that brings in the most cash?"*.

Definition 8 (Simple answer)
A simple answer is an answer $\mathcal{A} = (\mathscr{R}', p)$

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[5] In Catan, profit depends on the number on which the die falls.

where $\mathscr{R}'$ is a singleton.

$$\mathcal{A}_{simple} = (\{r\}, p).$$

Example 6 *Semantic representation of* ***Yellow***$_2$

$$[\![Yellow_2]\!] = (\{6\}, +).$$

Polar questions constitute a special case of interest, as for a polar question Q_p, $\mathscr{R}_{Q_p} = \emptyset$. A simple answer to a polar question is a confirmation or a negation of its declarative content. Thus, it corresponds (only) to the polarity: $(\emptyset, p), p \in \{+, -\}$.

Therefore, there is a difference between a simple answer to a (*wh*- or disjunctive) question, where $\mathscr{R}'$ is a singleton, and an answer to a polar question, where $\mathscr{R}'$ is empty. This difference allows us to argument for the pair model, as the first part of the pair models the informational content, needed to complete the dialogue, while the polarity is the way this element is included in the dialogue.

Example 5 shows that it is possible to find straightforward examples in real-life data that fit the simple answers definition. Yet, several problems frequently occur. First, while classifying answers by types is a difficult problem, finding what segment of data is an answer is a whole other problem of its own.

Example 7 *Simple answer, DinG*

Yellow$_1$ *Tu as fait combien ?*
Yellow$_1$ *"How many did you make?"*

Red$_2$ *oh oui 11 d'accord*
Red$_2$ *"Oh yes 11 OK"*

In example 7, the simple answer is *"11"*, but it is surrounded by phatic elements (*"Oh yes"* and *"OK"*). If **Yellow**$_1$ was a polar question, these phatic elements could have been simple answers. Therefore, any operationalization of our approach first involves identifying the span of the answers.

Example 8 *Simple answer, DinG*

Yellow$_1$ *Tu veux pas faire d'échange ?*
Yellow$_1$ *"Don't you want to make a trade?"*

Red$_2$ *Non*
Red$_2$ *"No"*

Another usual difficulty lies in the treatment of interro-negatives and their answers. **Yellow**$_1$ is a negative polar question, its declarative content is $decl(\textbf{Yellow}_1)$ = *"**Red** doesn't want to make a trade"*. If **Red** answers *"Yes"*, this answer validates the declarative content. However, the actual answer (**Red**$_2$) also validates the declarative content, while being supposedly a negative one. Different languages treat these constructions in different ways, in French it is possible to force the negation of a negative declarative content (therefore, to refuse the informative content of the question) by using the word *"si"* instead of *"oui"* or *"non"* (*"yes"* or *"no"*).

5.2 Complex answers and answer properties

Human communication heavily relies on logical inferences, ambiguities and, in general, pragmatics. Therefore, there are types of answers that are not as direct as the simple ones, as they don't give the requested information right away. The following develops on the four other descriptions from (Ginzburg, 2012).

5.2.1 Aboutness

When answers are not simple ones, different cases emerge. For polar questions, sometimes the answer is not a straight confirmation or a straight negation of the informational content. It is the case for conditional answers (*"if* `condition` *then yes"*) and answers under modalities (*"maybe"*, *"probably"*,*"possibly not"*).

Example 9 *DinG Corpus, aboutness*

Red$_1$ *Tu fais quelque chose ?*
Red$_1$ *"Are you doing something?"*

Yellow$_2$ *Ah ben j'ai construit 2 chemins si tu veux j'ai pas l'habitude de faire des trucs de fou comme ça*
Yellow$_2$ *"Well I built 2 roads you know I'm not used to doing crazy stuff like that"*

In example 9, **Red** asks a polar question. **Yellow** answers with a long sentence that amounts to a negative answer, but a human observer needs to make an inferential step to be able to deduce this: as **Yellow** is not used to *'doing crazy stuff like that'*, she will not be doing a lot of that, so she will not be doing something at the present moment. For discussions of these types of enthymematic reasonments, see (Breitholtz, 2014).

Wh-questions can be answered with disjunctive answers, presenting several possible short answers (in the context of example 5, *"The 3 or the 6, I don't remember"*) or with quantified answers (including generalized quantifiers such as *"at most"*, *"a few"*, *etc.*).

Example 10 *Aboutness, DinG*
Blue$_1$ *Qui se fait souvent de la pierre ?*
Blue$_1$ *"Who often makes stone?"*

White$_2$ *Euh, je m'en suis faite une seule depuis tout à l'heure*
White$_2$ *"Uh, I've only made one since earlier"*

In this example, **White**'s answer allows us to rule her out of the set of players among whom we are looking for the ones that often make stone. Thus, this answer gives additional information but doesn't completely solve the issue raised by **Blue**. This explains why $\mathscr{R}_Q$ always contains a set of possible answers to the question Q.

Computationally, this corresponds to the creation of $\mathscr{R}_2 \subseteq \mathscr{R}_{\mathbf{Blue}_1}$ by adding the information brought by the predicates introduced by the answer.

Example 11 *Computation of $\mathscr{R}_{\mathbf{Blue}_1}$, see example 10.*
In this example, we simplify the representation and we do not consider the temporal relation, thus we remove the representation of "since earlier".

$$\begin{aligned}
[\![\mathbf{Blue}_1]\!] &= \lambda x.\exists e.\exists y.make(e) \wedge Ag(e,x) \\
&\quad \wedge stone(y) \wedge Th(e,y) \\
&\quad \wedge often(e) \\
\mathscr{R}_{\mathbf{Blue}_1} &= \lambda x.\exists e.make(e) \wedge Ag(e,x) \\
&\quad \wedge often(e)
\end{aligned}$$

$\mathscr{R}_2$ is then built based on $[\![\mathbf{White}_2]\!]$:

$$\mathscr{R}_2 = \mathscr{R}_{Blue_1} \oplus [\![\mathbf{White}_2]\!],$$

where $\oplus$ is defined as a dynamic conjunction of the predicates introduced in the answer with an opening of the scope of λ. It works as if the λ was removed while the conjunction operates and goes back in once it is done.

$$\begin{aligned}
[\![\mathbf{White}_2]\!] &= \exists e.\exists y.make(e) \wedge Ag(e,\mathbf{White}) \\
&\quad \wedge stone(y) \wedge Th(e,y) \\
&\quad \wedge Amount(y,1) \\
\mathscr{R}_2 &= \lambda x.\exists e.\exists e'.\exists y.\exists y'.make(e) \\
&\quad \wedge Ag(e,x) \wedge often(e) \\
&\quad \wedge make(e') \wedge Ag(e',\mathbf{White}) \\
&\quad \wedge stone(y') \wedge Th(e',y') \\
&\quad \wedge Amount(y,1)
\end{aligned}$$

The property holds because $Amount(y,1)$ is about $\neg often(e')$. Thus $\mathbf{White}_2$ negates the question $\mathbf{Blue}_1$.

5.2.2 Strongly exhaustive answer

An answer A is *strongly exhaustive* for a question Q if and only if A is true and entails all the A_i that are simple answers to Q, (Ginzburg, 2012).

Intuitively, an answer is considered to be strongly exhaustive if independently from what comes next in the course of the dialogue, this answer cannot become more precise. It isn't necessary a simple answer, but the pragmatic environment of the dialogue allows us to approximate it as such. Thus, for a question Q, a strongly exhaustive answer $A = (\mathscr{R}', p)$ is such that $\mathscr{R}' = \mathscr{R}_Q$. $\mathscr{R}'$ is such that for all $A_i = (\mathscr{R}_i, p_i)$ a simple answer, $\mathscr{R}' \oplus \mathscr{R}_i = \mathscr{R}'$. Formally, this amounts to producing a fixed point on the objects $\mathscr{R}$.

We have not found examples of strongly exhaustive answers in DinG yet. Example 12 presents a constructed example of a strongly exhaustive answer in DinG's context.

Example 12 *Strongly exhaustive answer*

Red$_1$ *Tu veux quoi contre du blé ?*
Red$_1$ *"What do you want to trade for wheat?"*
Yellow$_2$ *De la pierre ou du bois*
Yellow$_2$ *"Stone or wood"*

Yellow$_2$ is true and entails both *"stone"* and *"wood"*, that are simple answers to **Red**$_1$.

5.2.3 Potentially resolving answer

Following (Ginzburg, 2012), a *potentially resolving answer* is an answer that either brings a simple answer, either shows that there is no answer.

Example 13 *Strongly exhaustive answer (self), DinG*

Yellow$_1$ *Alors qu'est-ce que je peux faire avec ça ?*
Yellow$_1$ *"So what can I do with this?"*

Yellow$_2$ *Euh ben rien en gros rien du tout*
Yellow$_2$ *"Uh, well, nothing, basically nothing at all"*

This characterisation of an answer is interesting as it seems to come directly from pragmatics. It finds an impact directly in our model. This definition supposes that the question is solved but doesn't specify the origin of the information that solves the question. It may come from the first component of the answering couple (the information itself), so from an effective answer. It may also come from the second component of the couple, the polarity. It is actually also possible that there is no answer. We make the choice here to suppose that there is an answer and that its informational content comes from $\mathscr{R}'$.

In example 13, **Yellow** both asks the question and gives the answer. Here, the resolution of the question comes directly from the information contained in the answer. The question/answer mechanism is covertly used both to support **Yellow**'s thinking process and to convey information to the other players.

5.2.4 Question/question relations

Knowing that it's possible to answer a question with a question forces us to consider the interactive aspect of dialogues, drawing us closer to the discursive modeling in the tradition of (Asher et al., 2003). This reference gives us the definition of a `Question elaboration` that stresses out the relation between two questions linked in a way such that any answer to the second one gives a strategy that leads to the solving of the query of the first one.

Example 14 *DinG Corpus, question/question*
White$_1$ *Tu as combien de moutons ?*
White$_1$ *"How many sheep do you have?"*

Blue$_2$ *Tu voudrais combien de moutons ?*
Blue$_2$ *"How many sheep would you like?"*

Intuitively, this means that it is possible to build $\mathscr{R}_{\mathbf{White}_1}$ but it is not possible to specify an answer element using $[\![\mathbf{Blue}_2]\!]$. It is not even possible to specify a subset of $\mathscr{R}_{\mathbf{White}_1}$ as a case of aboutness. The strategy here is to define a new $\mathscr{R}$ from $\mathscr{R}_{\mathbf{White}_1}$, using $[\![\mathbf{Blue}_2]\!]$, to allow the interaction to progress. $\mathscr{R}$ is such that $b \in \mathscr{R}$ if $\forall a.(b \vdash a) \wedge (a \in \mathscr{R}_{\mathbf{White}_1})$.

5.2.5 Other answers

The statistical and linguistic studies from (Blandón et al., 2019; Amblard et al., 2019) show the existence of two additional categories of answers: `Uncertain` and `Unknown`.

Example 15 *DinG Corpus, Uncertain*
Red$_1$ *J'ai le droit de le dire ça ? Ce que tu m'as piqué ?*
Red$_1$ *"Can I say that? What you stole from me?"*

Yellow$_2$ *J'en sais rien je pense c'est pas dramatique si les gens savent un peu euh ce que tu as fait*
Yellow$_2$ *"I don't know, I think it's not a big deal if people know a little bit about, uh, what you did"*

These concepts can be defined in our model. An `Uncertain` answer corresponds to the characterisation of an answer whose link with the question Q cannot be stated explicitly. Here, it is equivalent to saying that we don't know whether this answer is part of $\mathscr{R}_Q$, or, rather, that we don't know how to check whether it's the case. An `Unknown` answer means that we don't have access to the answer, either because of our lack of knowledge, thus making $\mathscr{R}_Q$ contain all the possible entities in the world, or because our knowledge base is not specific enough, making the cardinal of $\mathscr{R}_Q$ too big.

6 Clarification requests

(Purver, 2004) lists eight clarification request (CR) types, see table 2. Our study shows that the effect on preceding utterances of these different clarification requests in dialogue can be modeled using the functions `CF` and `CF+`, see table 3 for a summary of our approach. We group clarification requests by similarity of action on the preceding utterances.

Repetition requests (Wot, exp) `Wot` is a category of CRs that is used to request a repetition of an utterance or part of it.

Example 16 *DinG Corpus, Wot*
Blue$_1$ *Je suppose que personne ne veut du blé contre euh un bois euh un argile?*
Blue$_1$ *"I guess no one want a wheat for a wood uh a clay?"*

Category	Description	Example
Wot	words used to request repetition	Eh? / What? / Pardon?
Explicit (exp)	context-independent CRs	What did you say? / Did you say ‘Bo’? / What do you mean ‘leave’?
Literal Reprise (lit)	verbatim repetitions of the troubled utterance (while changing the interlocutor-oriented indexicals)	Did BO leave? / Did Bo LEAVE?
Wh-substituted Reprise (sub)	lit where a constituent is replaced by a *wh*-phrase	Did WHO leave? / Did Bo WHAT?
Reprise sluice (slu)	bare *wh*-phrase used as CR	Who? / What? / Where?
Reprise Fragments (RF)	bare phrase used as CR	Bo? / Leave?
Gaps	omitted targeted constituent	Did Bo ...?
Fillers	guess for the utterance intended in the unfinished antecedent sentence	A: Did Bo... B: Win?

Table 2: Categories of clarification requests, (Purver et al., 2003)

Yellow$_2$ *Quoi ?*
Yellow$_2$ *“What?”*

`exp` has the same effect as `Wot` but is produced by using an explicit question, that can be understood without knowing the exact context.

Example 17 *DinG Corpus, Explicit request*[6]
Blue$_1$ *Est-ce que quelqu’un voudrait m’échanger un blé contre un bois?*
Blue$_1$ *“Does someone want to trade a wheat for a wood with me?”*

Yellow$_2$ *C’est dans quel sens tu dis pas dans quel sens?*
Yellow$_2$ *“Which way you are not saying which way?”*

Both these categories of CR request repetition, rephrasing. `Wot` creates a new $\mathscr{R}$ that we know nothing about. It can be completely unrelated to the old one. `exp` creates a $\mathscr{R}_{new}$ that we can only characterize by $\mathscr{R}_{old} \cap \mathscr{R}_{new} \neq \emptyset$.

Example 18 *Explicit clarification request, DinG*
Red$_1$ *Quelqu’un veut m’échanger de l’argile ?*
Red$_1$ *“Does someone want to trade clay with me?”*

Blue$_2$ *Tu as de l’argile ou tu veux de l’argile ?*
Blue$_2$ *“Do you have clay or do you want clay?”*

Red$_3$ *Je veux de l’argile*
Red$_3$ *“I want clay”*

In example 18, **Blue** makes an explicit clarification request using a fully formed disjunctive question. Then, **Red**$_3$ is a simple answer.

Utterance reprises (lit, sub) `lit` is a repetition of the utterance that needs to be clarified. The interlocutor-oriented indexicals change and the prosody is used to stress out the interrogated part. `sub` acts as `lit`, it is a repetition of the utterance that needs to be clarified, but the interrogated part is replaced by a *wh*-phrase. `lit` and `sub` both act as `CF` on $\mathscr{R}$, on predicates and their arguments for `lit` and on thematic roles for `sub`.

Phrase reprises (slu, RF) `slu` is a bare *wh*-phrase, it is an anaphoric CR. `RF` is a bare phrase that is not a *wh*-phrase. `slu` creates a *wh*-question while `RF` creates a polar question, when combined with the previous utterance.

Example 19 *DinG Corpus, CR*
Blue$_1$ *2 pierres contre 1 argile ?*
Blue$_1$ *“2 stones for 1 clay?”*

Red$_2$ *2 pierres ?*
Red$_2$ *“2 stones?”*

These CRs shift the focus of the conversation while not changing the $\mathscr{R}$. To model this effect, we use $\texttt{CF}_{id}$: `CF` that takes as arguments $\mathscr{R}$, a predicate of $\mathscr{R}$, and the same predicate of $\mathscr{R}$. $\texttt{CF}_{id}$ leaves $\mathscr{R}$ unchanged.

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[6] Is it that **Blue** gives a wheat to get a wood or the other way around?

Category	**Effects of CRs on $\mathscr{R}$**
Wot	$\mathscr{R}_{new}$
Explicit (exp)	$\mathscr{R}_{new}$
Literal Reprise (lit)	`CF`
Wh-substituted Reprise (sub)	`CF`
Reprise sluice (slu)	$\mathtt{CF}_{id}$
Reprise Fragments (RF)	$\mathtt{CF}_{id}$
Gaps	`CF+`
Fillers	`CF+`

Table 3: Effects of clarification requests on the relevant response set

Example 20 *Reprise Fragment, DinG*

Blue$_1$ *Quel goût, les chips ?*
Blue$_1$ *"The chips - what flavor?"*

Red$_2$ *Mais elles sont juste dehors*
Red$_2$ *"[but] they're right outside"*

Blue$_3$ *Non mais quel goût ?*
Blue$_3$ *"No, [but] what flavor?"*

In this example, **Blue**$_3$ is a question that cannot be understood without the context given by the previous dialogue turns. In that case, we use $\mathscr{R}_{Blue_1}$ to built the representation of **Blue**$_3$.

Gaps & fillers `Gap` is a CR that creates a question by omitting the interrogated constituent in an utterance. `Gap` can create a question from a declarative sentence or a question likewise. `Fillers` act as counterparts for `Gaps` as `Fillers` are attempts at guessing a way to complete incomplete utterances or `Gaps`. These CRs request additional information, so their effect on $\mathscr{R}$ is modeled by `CF+`.

7 Conclusions and further work

We introduce a model for the question-answer relationship and for the articulation of different types of utterances (questions, answers, clarification requests) in dialogue. Based on the descriptions given in (Ginzburg, 2012), we define the relevant response set $\mathscr{R}_Q$ w.r.t a question Q, which helps us to characterise the utterances that can follow Q. We also design set operators `CF` and `CF+`, which implement modifications in the content of sets. We use them to reflect the effect of clarification requests on preceding utterances. The modelisation of different types of answers and of clarification requests directly follows from the definitions of $\mathscr{R}_Q$ and `CF`, `CF+`, without having to add new properties or define new objects.

Though this point is not explicitly addressed here, the methodological and technical tools that are used to produce the logical semantic representations have been developed for years (see for example (Pogodalla, 2004)). The model presented here is quite simple as it is based on a small amount of elementary types and few objects. Yet, it allows us to gather several concepts that are difficult to conciliate such as compositional approaches to language and corpus-based observations modeling.

The perspectives for this work are now on one hand to apply the model on real-life data and on the other hand to make the computation of representations operational. However, though this last part is the most important one, it still needs for our model to be included in a more global system that takes into account different phases of dialogue and the way they articulate (Boritchev and Amblard, 2019b).

A substantial issue for our model is to include a proper treatment of Non-Sentential Utterances, which are important in the articulation of spontaneous speech. In the same perspective, we need to give a formal account of phatic expressions. Both phenomena seem to follow the same kind of process and need a specific treatment. Another relevant perspective is to propose an implementation that would be able to explicitly compute the answers to questions. To this end, we will need to include a dialogue parser to our pipeline.

Our next step will be to extend and polish this model. Some of the types we presented in section 4 may seem quite ad-hoc, but it is actually possible to to produce them in a systematic way. We also want to enrich our model by anchoring it in Inquisitive Logic (Ciardelli et al., 2017). Then, we want to address dynamicity-related issues in dialogue by taking into account the contexts and the common ground (Stalnaker, 2002): what does a player know and/or believe, what knowledge and/or belief is common to all the players, and how do those evolve as the multilogue unfolds. To these ends, we want to adapt Continuation Style Dynamic Semantics (De Groote, 2006) for dialogue and integrate the result in our model.

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