TTR for Natural Language Semantics

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1 Introduction

Given the state of the art, a simple actual conversation such as (1) still constitutes a significant challenge to formal grammar of just about any theoretical flavour.

(1)

As we note in the diagram above, this little dialogue involves a variety of theoretically difficult phenomena: it involves three rather than two participants, is hence a multi-party dialogue; it features disfluencies, a variety of types of non-sentential utterances, partial comprehension, disagreement, and an instance of self answering. Making sense of all these phenomena in a systematic way is a challenge undertaken in the TTR–based dialogue framework KoS (Ginzburg, 2012) and we will illustrate throughout the paper how the various ingredients that make up TTR allow this challenge to be met.

There are, nonetheless, a number of well established paradigms for doing formal semantics and the obvious question to ask is: why develop a distinct framework? We will illustrate throughout the paper intrinsic problems for frameworks such as possible worlds semantics and typed-feature structure (TFS)–based approaches:

1 The conversation occurs in the block G4K of the British National Corpus (BNC).
• **Semantic ontology**: Why not a possible worlds–based approach? There are well known problems for this strategy that revolve around its coarseness of grain. These are often ignored (folk assumption: ‘...the attitudes are difficult and primarily a philosophical problem...’) Whether or not this is true we point to the problems posed by negation which cannot be brushed off so easily.

• **syntax-semantics interface**: Why is a TFS-based approach to a syntax-semantics interface, as in frameworks such as Head-driven Phrase Structure Grammar (HPSG) (Sag *et al.* (2003)) and in Sign-based Construction Grammar (Michaelis (2009)) insufficient? Here again, there are well known problems (lack of proper binding, functions) and these can be solved in standard $\lambda$-calculus based approaches. We will point to issues that are difficult to the latter such as clarification interaction and quotation.

Our claim is that TTR enables a uniform theory of grammar, semantics, and interaction that can tackle such problems, while allowing one to maintain past insights (emanating from Montague Semantics and Discourse Representation Theory) and also, we think, future directions (e.g. probabilistic semantics).

This article is structured as follows: the basics of TTR are described in section 2. Subsequently, in sections 3–5 we use this to sketch fundamental notions of grammar, semantic ontology, and dialogical interaction. These are eventually illustrated in more detail in sections 6–8 which deal with meta-communicative interaction, negation, quantification, and, more briefly, non-sentential utterances, dysfluencies, and conversational genres.
2 A theory of types and situations

2.1 Type theory and perception

In classical model theoretic semantics (Montague, 1973, 1974) there is an underlying type theory which presents an ontology of basic classes of objects such as, in Montague’s type theory, entities, truth values, possible worlds and total functions between these objects. Here we will make use of a rich type theory inspired by the work of Martin-Löf (1984) and much subsequent work on this kind of type theory in computer science. For a recent example relating to natural language see Luo (2011). In a rich type theory of the kind we are considering there are not only types for basic ontological categories but also types corresponding to categories of objects such as Tree or types of situations such as *Hugging of a dog by a boy*. A fundamental notion of this kind of type theory is that of a judgement that an object (or situation) *a* is of type *T*, in symbols, *a* : *T*. In our view judgements are involved in perception. In perceiving an object we assign it a type. The type corresponds to what Gibson (1986) (and following him in their theory of situation semantics, Barwise & Perry, 1983) would call an invariance. In order to perceive objects as being of certain types, agents must be attuned to this invariance or type. We take this to mean that the type corresponds to a certain pattern of neural activation in the agent’s brain. Thus the types to which a human is attuned may be quite different from those to which an insect is attuned. A bee landing on a tree does not, presumably, perceive the tree in terms of the same type *Tree* that we are attuned to.

2.2 TTR: Type theory with records

The particular type theory we will discuss here is TTR which is particular variant of Type Theory with Records. The most recent published reference which gives details is Cooper (2012). An earlier treatment is given in Cooper (2005a) and Cooper (2005c) discusses its relation to various semantic theories. Here we will give a less detailed formal treatment of the type theory than in the first two of these references. We start by characterizing a system of basic types as a pair consisting of a non-empty set of types, *Type*, and a function, *A*, whose domain is *Type* and which assigns to each type in *Type* a (possibly empty) set which does not overlap with *Type*. We say that *a* is of type *T* (in *Type*), *a* : *T*, according to \(<\text{Type}, A>\) just in case *a* ∈ *A*(*T*). In general we will think of basic types as corresponding to basic ontological categories. The basic type we will use in this section is *Ind* for individuals.

We will use complex types for types of situations. The simplest complex type of situation is constructed from a predicate together with some appropriate arguments to the predicate. Consider, for example, the type of situation where a boy called Bill (whom we will represent by *b*) hugs a dog called Dinah, (represented by *d*). The type of situation in which Bill hugs Dinah will

[Montague 1973, 1974] [Martin-Löf 1984] [Luo 2011] [Cooper 2012] [Cooper 2005a] [Cooper 2005c]
be constructed from the predicate ‘hug’ together with the arguments \( b \) and \( d \).

This type is represented in symbols as \( \text{hug}(b,d) \). Here we are treating ‘hug’ as a predicate which has \( \text{arity} \langle \text{Ind}, \text{Ind} \rangle \), that is, it requires two individuals as arguments. Sometimes we may allow predicates to have more than one arity, that is they may allow different configurations of arguments. In this case we say that the predicate is \textit{polymorphic}. Types like this which are constructed with predicates we will call \textit{ptypes}. A system of types containing ptypes, a \textit{system of complex types}, will be an extension of a system of basic types \( \langle \text{BType}, A \rangle \), \( \langle \text{Type}, \text{BType}, \text{PType}, \langle A, F \rangle \rangle \) where \text{PType} is a set of ptypes constructed from a particular set of predicates and arities associated with them by combining them with all possible arguments of appropriate types according to the type system and \( F \) is a function whose domain is \text{PType} which assigns a (possibly empty) set of situations to each ptype. The set \text{Type} includes both \text{BType} and \text{PType}.

This gives us a system of types which will allow us types of situations where particular individuals are related to each other. However, we want to be able to characterize more general types of situation than this, for example, the type of situations where some boy hugs a dog, that is, the type of any “boy hugs dog” situation. There are a number of ways to characterize such more general types in type theory. In TTR we use record types. The type of situation where a boy hugs a dog could be the following record type:

\[
\begin{align*}
  x & : \text{Ind} \\
  c_{\text{boy}} & : \text{boy}(x) \\
  y & : \text{Ind} \\
  c_{\text{dog}} & : \text{dog}(y) \\
  e & : \text{hug}(x,y)
\end{align*}
\]

This record type consists of five \textit{fields} each of which consists of a \textit{label} (such as ‘x’ or ‘c\text{dog}’) and a type (such as \text{Ind} or ‘\text{dog}(y)’). Each field is an ordered pair of a label and a type and a record type is a set of such fields each of which have a distinct label. We use labels like ‘x’ and ‘y’ for fields introducing individuals and labels like ‘c\text{pred}’ for fields introducing types which are ptypes with the predicate \text{pred} representing constraints or conditions (hence ‘c’) on objects in other fields. We will often use the label ‘e’ for the type representing the main event such as hugging. A record of this type is a set of fields with labels and objects such that no two fields have the same label, there is a field with each of the labels in the record type and the object in the field is of the type in the corresponding field in the record type. Note that there can be more fields in the record with labels not mentioned in the record type. If this type is non-empty there will be a boy and a dog such that the boy hugs the dog. Thus this type could be used to represent the content of a \textit{boy hugs a dog}.

That is, we use the type to play the role of a proposition in other theories. (Later we will introduce a more complex notion of proposition which builds on the type.)
Technically, we have cheated a little in this presentation of record types. ‘boy(x)’, ‘dog(y)’ and ‘hug(x,y)’ are not technically ptypes since ‘x’ and ‘y’ are labels, not individuals as required by the arities of these predicates. What we mean by this notation is the ptype we can construct by substituting whatever individuals occur in the ‘x’ and ‘y’ fields of the record we are checking to see whether it belongs to the type. Thus the ptypes will be different depending on which record you are checking. The official notation for this record type makes this more explicit by introducing functions from individuals to ptypes and pairing them with a list of path names indicating where in the record one should look for the arguments to the functions.

\[
\begin{align*}
x & : \text{Ind} \\
c_{\text{boy}} & : \langle \lambda v : \text{Ind}(\text{boy}(v)), \langle x \rangle \rangle \\
y & : \text{Ind} \\
c_{\text{dog}} & : \langle \lambda v : \text{Ind}(\text{dog}(v)), \langle y \rangle \rangle \\
e & : \langle \lambda v_1 : \text{Ind}(\lambda v_2 : \text{Ind}(\text{hug}(v_1,v_2))), \langle x,y \rangle \rangle 
\end{align*}
\]

There is good reason to use this more complex notation when we deal with more complex record types which have record types embedded within them. However, for the most part we will use the simpler notation as it is easier to read.

However, functions from objects to types, dependent types, will play an important role in what we have to say below.

In record types we will frequently make use of manifest fields\footnote{This notion was introduced in Coquand et al. (2004).} A manifest field $[\ell = a : T]$ is a convenient notation for $[\ell : T_a]$ where $T_a$ is a singleton type whose only witness is $a$. Singleton types are introduced by:

If $a : T$ then $T_a$ is a type.

$b : T_a$ iff $b = a$

### 2.3 Subtyping

An important notion in TTR is that of subtype since this is a central notion of inference in the system. $T_1$ is a subtype of $T_2$ ($T_1 \subseteq T_2$) just in case for all assignments to basic types it is the case that if $a : T_1$ then $a : T_2$. For more discussion of this notion see Cooper (2012).

### 2.4 Function types

If $T_1$ and $T_2$ are types, then so is $(T_1 \rightarrow T_2)$. $f : (T_1 \rightarrow T_2)$ iff $f$ is a function with domain $\{a : T_1\}$ and range included in $\{a : T_2\}$ that is, it is a total function from objects of type $T_1$ to objects of type $T_2$. A function is associated with a graph which is a set of ordered pairs as in the classical set theoretical model of a function. However, we allow more than one function to have the
same graph (thus making the functions intensional). We also require that for each graph whose domain (i.e. left projection) is the set of witnesses of a type and whose range (i.e. right projection) is included in the set of witnesses of another type there is a function which has this graph. Finally we stipulate that types \((T_1 \rightarrow T_2)\) and \(T_1\) are incompatible. That is, functions cannot apply to themselves.

2.5 Complex types corresponding to propositional connectives

If \(T_1\) and \(T_2\) are types then so are \((T_1 \land T_2)\), \((T_1 \lor T_2)\) and \(\neg T\). \(a : (T_1 \land T_2)\) iff \(a : T_1\) and \(a : T_2\). \(a : (T_1 \lor T_2)\) iff \(a : T_1\) or \(a : T_2\). \(a : \neg T\) iff there is some type \(T_2\) which is incompatible with \(T_1\) such that \(a : T_2\). \((T_1 \land T_2)\) is incompatible with \(T_2\) just in case there is no assignment to basic types such that there is some \(a\) such that \(a : T_1\) and \(a : T_2\). That is, it is impossible for any object to belong to both types. This is a non-classical treatment of negation which we will discuss in Section 7.1.

Occasionally we will need types which are infinite joins of types in order to characterize function types that we need. We will represent these using a subscripted \(\bigvee\). Thus if \(T_1\) and \(T_2\) are types, then

\[
\bigvee_{X \subseteq T_1} (X \rightarrow T_2)
\]

is a type. \(f : \bigvee_{X \subseteq T_1} (X \rightarrow T_2)\) iff \(f : (T \rightarrow T_2)\) for some type \(T\) such that \(T \sqsubseteq T_1\).

As we have record types in our system we will be able to form meets, joins and negations of these types just like any other. When we form the meet of two record types, \(T_1 \land T_2\) there is always a record type \(T_3\) which is equivalent to \(T_1 \land T_2\) in the sense that no matter what we assign to our basic types anything which is of \(T_1 \land T_2\) will be of type \(T_3\) and vice versa. \(T_3\) is defined using the merge operator \(\land\). Thus, \(T_1 \land T_2\) is the merge of the two types \(T_1, T_2\). If at least one of the two types is not a record type it is identical with the meet \(T_1 \land T_2\). The basic idea of merge for record types is illustrated by the following examples:

\[
\begin{align*}
[f;T_1] \land [g;T_2] & = [f;T_1] \\
[f;T_1] \land [f;T_2] & = [f;T_1 \land T_2]
\end{align*}
\]

(For a full definition see Cooper, 2012) Merge corresponds to unification in feature based systems such as HPSG.

In addition to merge we also introduce asymmetric merge, \(T_1 \land T_2\). This is defined like ordinary merge except that in the case where one of the types is not a record type \(T_1 \land T_2 = T_2\). This notion (which is discussed in detail in work in progress) is related to that of priority unification (Shieber, 1986).
2.6 Set and list types

If \( T \) is a type then \( \{ T \} \) and \([ T ]\) are types. \( A : \{ T \} \) just in case \( A \) is a set and for any \( a \in A, a : T \). Similarly, \( L : [ T ] \) just in case \( L \) is a list and any member, \( a \), of \( L \) is such that \( a : T \).

We will also introduce a type \( \text{Poset}(T) \) which can be regarded as

\[
\begin{bmatrix}
\text{set} : \{ T \} \\
\text{rel} : \{ \left[ \begin{array}{c}
\text{left} : T \\
\text{right} : T
\end{array} \right] \} \\
\text{c}_{\text{po}} : \text{po}(\text{rel}, \text{set})
\end{bmatrix}
\]

where \( a : \text{po}(R, S) \) iff \( a = \langle R, S \rangle \) and \( R \) is a partial order on \( S \), that is, \( R \) is a set of pairs of members of \( S \) (coded as records with ‘left’ and ‘right’ fields as above) and \( R \) is reflexive or irreflexive, antisymmetric and transitive.

If \( a : T, P : \text{Poset}(T) \) and \( a \not\in P.\text{set} \), then \( a \oplus P : \text{Poset}(T) \) where \( a \oplus P \) is the record \( r : \text{Poset}(T) \) such that

\[
\begin{align*}
r.\text{set} & = P.\text{set} \cup \{ a \}, \\
for \ r.\text{rel} & = P.\text{rel} \cup \{ \left[ \begin{array}{c}
\text{left} = a \\
\text{right} = x
\end{array} \right] \mid x \in p.\text{set} \} \\
and \ r.\text{c}_{\text{po}} & = \langle r.\text{rel}, r.\text{set} \rangle.
\end{align*}
\]

2.7 The string theory of events

So far we have talked about situations or events in terms of ptypes or record types which have ptypes in some of their fields. This gives us a rather static view of events and does not give an analysis of the changes that take place as an event unfolds. A single type is rather like a snapshot of an event at one point of its development. In an important series of papers including [Fernando 2004, 2006, 2008, 2009], Tim Fernando has proposed that events should be analyzed in terms of strings of snapshots or observations. In TTR we adapt these ideas by introducing \( \text{regular types} \), types of \( \text{strings} \) of objects corresponding to the kinds of strings you find in regular languages in formal language theory (Hopcroft & Ullman 1979, Partee et al. 1990). Here is an account of the two main kinds of regular types that we will use here where we use \( a \overset{\cdot}{b} \) to represent the \( \text{concatenation} \) of two objects \( a \) and \( b \):

(1) if \( T_1, T_2 \in \text{Type} \), then \( T_1 \overset{\cdot}{T_2} \in \text{Type} \)

\[
a : T_1 \overset{\cdot}{T_2} \text{ iff } a = x \overset{\cdot}{y}, x : T_1 \text{ and } y : T_2
\]

(2) if \( T \in \text{Type} \) then \( T^+ \in \text{Type} \).

\[
a : T^+ \text{ iff } a = x_1 \overset{\cdot}{\ldots} \overset{\cdot}{x_n}, n > 0 \text{ and for } i, 1 \leq i \leq n, x_i : T
\]

\( T_1 \overset{\cdot}{T_2} \) is the type of strings where something of type \( T_1 \) is concatenated with something of type \( T_2 \). \( T^+ \) is the type of non-empty strings of objects of type \( T \). Suppose for example that we want to represent the type a game of fetch as a game played between a human, \( a \), and a dog, \( b \), involving a stick, \( c \), in which the human picks up the stick, attracts the attention of the dog, and throws
the stick, whereupon the dog runs after the stick and picks it up, returning it
to the human, after which the cycle can start from the beginning. The type
of this event would be:

\[
\text{pick}_\text{up}(\text{a}, \text{c}) \sim \text{attract}_\text{attention}(\text{a}, \text{b}) \sim \text{throw}(\text{a}, \text{c}) \sim \text{run}_\text{after}(\text{b}, \text{c}) \sim \text{pick}_\text{up}(\text{b}, \text{c}) \sim \text{return}(\text{b}, \text{c}, \text{a})
\]

2.8 Inference from partial observation of events

An important fact about our perception of events is that we can predict the
type of the whole event when we have only perceived part of the event. Thus if
we see a human and a dog playing with a stick and we see the human pick up
the stick and attract the dog’s attention we might well predict that the type
of the whole event is one of playing fetch. We can represent this prediction by
a function:

\[
\lambda r : \left[ \begin{array}{c}
x : \text{Ind}c\text{human}(x) \\
y : \text{Ind}c\text{dog}(y) \\
z : \text{Ind}c\text{stick}(z) \\
\end{array} \right] \rightarrow \left[ \begin{array}{c}
e : \text{play}_\text{fetch}(r.x, r.y) \\
\end{array} \right]
\]

Notice that this function is what we have called a dependent type, that is, it
takes an object (in this case the observed situation) and returns a type (in this
case the type of the predicted situation). Notice that this ability to predict
types of situations on the basis of partial observations is not particular to
humans. The dog realizes what is going on and probably starts to run before
the human has actually thrown the stick. However, in the Section 3 we will
suggest that humans build on this ability in their perception and analysis of
speech events.
3 Grammar in TTR

In Section 2 we suggested that an important capability that agents have is the prediction of the type of a complete event on the basis of a partial observation of an event and we suggested that functions from observed situations to predicted situation type (a kind of dependent type) can be used in modelling this. We discussed the example of the game of fetch where observation of some part of the game could lead you to infer that the whole event you are in the process of observing is an instance of the game of fetch. Very similar inferences are involved in the perception of linguistic events, though there are also some important differences. In the case of the game of fetch the predicted type is a type of situation which you could in principle perceive completely. In the example we gave you are inferring the nature of the event as it will develop later in time. The case of linguistic perception is rather more abstract. We are inferring types which may hold simultaneously with what we have observed and the predicted event types may be of events that are not directly perceivable. Thus we are able to perceive events belonging to phonological or phonetic types but we infer from these types relating to syntactic and semantic structure whose instances are not directly perceivable. It is this kind of reasoning about abstract objects which seems so important to human linguistic ability. Nevertheless the fundamental mechanism is the same: we are mapping from an observation to a type of something unobserved. The evolutionary step is to allow the type for what has not been observed to be of something that is not directly perceivable.

Grammar rules involve a prediction on the basis of a string of linguistic events. Thus they are functions of the form:

$$\lambda s : T_1 \ldots \sim T_n(T)$$

where the $T_i$ and $T$ are sign types, which, as we will see below, are types which have both a directly perceivable and a non-directly perceivable component. Thus grammar rules are functions from strings of linguistic events to a type of a single linguistic event. An example would be the observation of a string consisting of a noun-phrase event followed by a verb-phrase event and predicting that there is a sentence event, that is, what is normally written in linguistic formalisms as the phrase-structure rule $S \rightarrow NP \ VP$.

Sign types correspond to the notion of sign in HPSG (Sag et al., 2003). The type $\text{Sign}$ could be thought of as:

$$\begin{align*}
\text{Sign} &= \begin{cases}
\text{cat} : \text{Cat} \\
\text{cnt} : \text{Cnt}
\end{cases}
\end{align*}$$

$$\begin{align*}
\text{synsem} &= \begin{cases}
\text{cat} : \text{Cat} \\
\text{constits} : \{ \text{Sign} \}
\end{cases}
\end{align*}$$

$s$-event : $\text{SEvent}$

For more detailed discussion of the grammar discussed here and below see Cooper (2012).
although this, and also what follows below, could be adjusted to fit more
closely with your favourite version of HPSG. However, for technical reasons
having to do with recursion (ultimately signs may be contained within signs),
we have to define Sign as a basic type which meets the condition:

\[ r : \text{Sign} \text{ if } r : \begin{bmatrix} \text{s-event} : \text{SEvent} \\ \text{synsem} : \begin{bmatrix} \text{cat} : \text{Cat} \\ \text{constits} : \{ \text{Sign} \} \\ \text{cnt} : \text{Cnt} \end{bmatrix} \end{bmatrix} \]

We have introduced three new types here: SEvent, the type of speech events;
Cat, the type of categories and Cnt, the type of semantic contents. We will
take each of these in turn and return to the ‘constits’-field in synsem below.

A minimal solution for the type SEvent is

\[ \begin{bmatrix} \text{phon} : \text{Phon} \\ \text{s-time} : \text{TimeInt} \\ \text{uttat} : \text{uttered} \text{at} (\text{phon}, \text{s-time}) \end{bmatrix} \]

Here we have introduced the types Phon, phonology, and TimeInt, time in-
terval, which we will further specify below. A more detailed type for SEvent
might be:

\[ \begin{bmatrix} \text{e-time} : \text{TimeInt} \\ \text{e-loc} : \text{Loc} \\ \text{sp} : \text{Ind} \\ \text{au} : \text{Ind} \\ \text{phon} : \text{Phon} \\ \text{e} : \text{utter} (\text{sp}, \text{phon}, \text{au}, \text{e-time}, \text{e-loc}) \end{bmatrix} \]

where we have in addition fields for event location, speaker and audience. This
corresponds more closely to the kind of information we normally associate with
speech act theory (Searle [1969]). However, this type may be too restrictive:
more than one person may be in the audience; more than one speaker may
collaborate on a single speech event, as is shown by work on split utterances
(Purver et al. [2010]). For present purposes it will be sufficient to use the first
simpler type for speech events.

We will take the type Phon to be the type of a non-empty string of
phoneme utterances, that is Phoneme+. We could use phonetic symbols to
represent types of individual phoneme utterances. For example \( u : h \) would
mean that \( u \) is an utterance of the phoneme \( h \) (the phoneme being modelled
as a TTR type). \( u : h \rightarrow^{\text{xy}} \) would mean that \( u \) is an utterance of the phoneme
string which we denote in orthography by ‘hi’. It is not our intention to give
detailed account of phonology here and we will represent this string type
using the orthography as hi. Note that hi is a subtype of Phon.

We define the type TimeInt, for time interval, to be
\[
\begin{array}{c}
\text{start} : \text{Time} \\
\text{end} : \text{Time} \\
\text{c<} : \text{start<end}
\end{array}
\]

where \text{Time} is a basic type whose witnesses are time points and < is a predicate (here used in infix notation) which requires that its first argument is ordered before its second argument.

The ‘constits’-field in synsem is for the set of constituents (including all constituents, not just daughters (immediate constituents)).

In Section 5 we will extend the definition of \text{Sign} to include a field for a dialogue game board as discussed there.
4 A theory of abstract entities

An ontology including abstract entities—including entities such as propositions, questions, and outcomes is a necessary ingredient for accounts of illocutionary acts such as assertion, querying, and commanding, as well as of attitude reports. Building on a conception articulated 30 years earlier by Austin [Austin (1961)], Barwise & Etchemendy (1987) developed a theory of propositions in which a proposition is a structured object $\text{prop}(s, \sigma)$, individuated in terms of a situation $s$ and a situation type $\sigma$. Given the ‘:’ relation between situations and their types there is a straightforward notion of truth and falsity:

\begin{align*}
\text{(2)} \\
&\text{a. } \text{prop}(s, \sigma) \text{ is true iff } s : \sigma (s \text{ is of type } \sigma).
\end{align*}

\begin{align*}
&\text{b. } \text{prop}(s, \sigma) \text{ is false iff } s : \neg \sigma (s \text{ is not of type } \sigma).
\end{align*}

A detailed such ontology extending the original situation semantics ontology was developed in Ginzburg & Sag (2000). This approach has subsequently been developed in TTR in works such as Ginzburg (2011, 2012). We start by discussing how to add propositions into TTR.

For many purposes the type theory already developed has entities that could be identified with Austinian propositions, an identification frequently assumed in past work in type theory via the slogan propositions as types. Cooper (2005b) develops the former in which a proposition $p$ is taken to be a record type. A witness for this type is a situation. On this strategy, a witness is not directly included in the semantic representation. Indeed, record types are competitive in such a role: they are sufficiently fine-grained to distinguish identity statements that involve distinct constituents. (3a) would correspond to the record type in (3c), whereas (3b) to the record type in (3d)). Moreover, in this set up substitutivity of co-referentials (3e) and cross-linguistic equivalents ((3e), the Hebrew equivalent of (3a)) can be enforced:

\begin{align*}
\text{(3)} \\
&\text{a. } \text{Enescu is identical with himself.}
\end{align*}

\begin{align*}
&\text{b. } \text{Poulenc is identical with himself.}
\end{align*}

\begin{align*}
&\text{c. } \{c : \text{Identical(enesco, enesco)}\}
\end{align*}

\begin{align*}
&\text{d. } \{c : \text{Identical(poulenc, poulenc)}\}
\end{align*}

\begin{align*}
&\text{e. } \text{He is identical with himself.}
\end{align*}

\begin{align*}
&\text{f. } \text{Enesku zehe leacmo.}
\end{align*}

A situational witness for the record type could also be deduced to explicate cases of event anaphora, as in (4); indeed, a similar strategy is invoked when in an analysis of nominal anaphora in Ginzburg (2012):

\begin{align*}
\text{(4)} \\
&\text{a. } \text{A: Jo and Mo got married yesterday. It was a wonderful occasion.}
\end{align*}
b. A: Jo’s arriving next week. B: No, that’s happening in about a month.

Nonetheless, here we develop an explicitly Austinian approach, where the situational witness is directly included in the semantic representation. The original Austinian conception was that $s$ is a situation deictically indicated by a speaker making an assertion—teasing the semantic difference between implicit and explicit witnesses is a difficult semantic task. The Austinian approach is important for negation (see section 7.1). Explicitly Austinian propositions can also play a role in characterizing the communicative process: in section 6 we will show that locationary propositions individuated in terms of an utterance event $u_0$ as well as to its grammatical type $T_{u_0}$ allows one to simultaneously define update and clarification potential for utterances. In this case, there are potentially many instances of distinct locationary propositions, which need to be differentiated on the basis of the utterance token—minimally any two utterances classified as being of the same type by the grammar.

Assuming we adopt an explicitly Austinian approach, then the type of propositions is the record type (5a). The correspondence with the situation semantics conception is quite direct. We can define truth conditions as in (5b).

$$(5)$$

a. $Prop =_{def} \left[ \begin{array}{c} \text{sit} : Rec \\ \text{sit-type} : RecType^\dagger \end{array} \right]$  

b. A proposition $p = \left[ \begin{array}{c} \text{sit} = s_0 \\ \text{sit-type} = ST_0 \end{array} \right]$ is true iff $s_0 : ST_0$

Here the type $RecType^\dagger$ is a basic type which denotes the type of records types closed under meet, join and negation. That is, we require:

(1) if $T:RecType$, then $T:RecType^\dagger$

(2) if $T_1, T_2:RecType^\dagger$, then $T_1 \land T_2, T_1 \lor T_2, \neg T_1:RecType^\dagger$

(3) Nothing is of type $RecType^\dagger$ except as required above.

If $p:Prop$ and $p$.sit-type is $T_1 \land T_2$ ($T_1 \lor T_2, \neg T$) we say that $p$ is the conjunction (disjunction) of

$\left[ \begin{array}{c} \text{sit} = p$.sit \\ \text{sit-type} = T_1 \end{array} \right]$ and

$\left[ \begin{array}{c} \text{sit} = p$.sit \\ \text{sit-type} = T_2 \end{array} \right]$ (the negation

$\left[ \begin{array}{c} \text{sit} = p$.sit \\ \text{sit-type} = T \end{array} \right]$). This means that Austinian propositions are not closed under conjunction and disjunction. You can only form the conjunction and disjunction of Austinian propositions which have the same situation. If $p_1$ and $p_2$ are Austinian propositions such that $p_1$.sit = $p_2$.sit, we say that $p_1$ entails $p_2$ just in case $p_1$.sit-type $\subseteq p_2$.sit-type.

A subtype of $Prop$ that will be important below is the type of locationary propositions $LocProp$. Locationary propositions are Austinian propositions about utterances. $LocProp$ is defined as

---

4 One could also construe $s$ as evidence (a body of knowledge, a database) which provides support (or otherwise) for the type $\sigma$. 
LocProp = def [sit : Sign
sit-type : RecType]

4.1 Questions

Given the existence of Austinian-like propositions and a theory of $\lambda$-abstraction
given to us by existence of functional types, it is relatively straightforward to
develop a theory of questions as propositional abstracts in TTR. Extensive
motivation for the view of questions as propositional abstracts is provided in
Ginzburg (1995a); Ginzburg & Sag (2000)—TTR contributes to this by pro-
viding an improved notion of simultaneous, restricted abstraction, as we will
see shortly.

A (basic, non-compound) question will be a function from records into
propositions. As such, questions are automatically part of the type theoretic
ontology. Let us start by considering some very simple examples of interrog-
atives and their TTR representations. (6) exemplifies the denotations (con-
tents) we can assign to a unary and a binary \textit{wh}-interrogative. We use $r_{ds}$
here to represent the record that models the described situation in the context. The
meaning of the interrogative would be a function defined on contexts which
provide the described situation and which return as contents the functions
given in (6). The unary question ranges over instantiations by persons of the
proposition “$x$ runs in situation $r_{ds}$” and the binary question ranges over in-
stantiations by pairs of persons $x$ and things $y$ of the proposition “$x$ touches
$y$ in situation $r_{ds}$”:

(6)

a. who ran

$\lambda r: x:\text{Ind}
\begin{array}{l}
\text{rest:person}(x)
\end{array}
\left(\begin{array}{l}
sit = r_{ds}
sit-type = [c:run(r.x)]
\end{array}\right)$

b. who touched what

$\lambda r: x:\text{Ind}
\begin{array}{l}
\text{rest1:person}(x)
\end{array}
\begin{array}{l}
\text{rest2:thing}(y)
\end{array}
\left(\begin{array}{l}
sit = r_{ds}
sit-type = [c:touch(r.x, r.y)]
\end{array}\right)$

What of polar questions? Ginzburg & Sag (2000) proposed that these are
0-ary abstracts, though the technical apparatus involved in explicating this
notion in their framework based on non-well-founded set theory was quite
complex. TTR, however, offers a simple way to explicate 0-ary abstraction.
If we think of a unary abstract as involving a domain type with one field for
an individual and a binary abstract as one whose domain type contains two
such fields etc, then by analogy the domain type of a 0-ary type would simply
be the empty type [ ] (that is, the type $Rec$ of records). This makes a 0-ary
abstract a constant function from the universe of all records . (7) exemplifies
this:

(7)
The fact that questions individually are part of the type theoretic world is not the end of the story. For various linguistic tasks (e.g. specifying the selectional requirements of verbs like ‘ask’, ‘wonder’, and ‘investigate’), and for various dialogical tasks (e.g. the formulation of various conversational rules) one needs to appeal to a type Question. This means that we need to have a characterization of this type within TTR. One such characterization is given in Ginzburg (2012). Here we offer a somewhat distinct and somewhat simpler characterization:

The domain of a question (polar or wh) is always characterized by a sub-type of RecType. Thus we define the type Question by

$$\text{Question} \overset{\text{def}}{=} \bigvee_{X \subseteq \text{RecType}} (X \to \text{Prop})$$

The type of polar questions, PolQuestion, is

$$\text{PolQuestion} \overset{\text{def}}{=} (\text{Rec} \to \text{Prop})$$

Answerhood is one of the essential testing grounds for a theory of questions. Abstracts can be used to underspecify answerhood. This is important given that NL requires a variety of answerhood notions, not merely exhaustive answerhood or notions straightforwardly definable from it. Moreover, as with questions, answerhood needs to be explicable type theory–internally. This is because answerhood figures as a constituent relation of the lexical entries of resolutive verbs and in rules regulating felicitous responses in dialogue management (see section 5.). For current purposes this means that we need to be able to define notions of answerhood as types.

There are a number of notions of answerhood that are of importance to dialogue. One relates to coherence: any speaker of a given language can recognize, independently of domain knowledge and of the goals underlying an interaction, that certain propositions are about or directly concern a given question. The simplest notion of answerhood we can define on the basis of an abstract is one we will call, following Ginzburg & Sag (2000), simple answerhood. In order to this we will use the following notion:

A proposition $p$ is an instantiation of a question $q$ just in case there is some $r$ in the domain of $q$ such that $q(r) = p$

---

5 The characterization here yields a type that strictly subsumes the type from Ginzburg (2012). For instance, the latter characterization only allows in as polar questions constant functions. We leave a detailed comparison to another occasion.

6 For more detailed discussion see Ginzburg & Sag (2000), Chapter 3, section 3.2 and Chapter 8, section 8.3.
(8) a. \( \alpha \) is a simple answer to \( q \) iff \( \alpha \) is an instantiation of \( q \) or the negation of an instantiation of \( q \).

Given these definitions it is straightforward to show:

(9) a. If \( q \) is an \( n \)-ary question of type \( (T \to \text{Prop}) \) and \( \alpha \) is a simple answer to \( q \) then there is some \( r : T \) such that \( \alpha \) is \( q(r) \) or \( \neg q(r) \).

b. In particular, if \( q \) is the polar question \( \lambda r : ![p] \) and \( \alpha \) is a simple answer to \( q \) then \( \alpha \) is either \( p \) or \( \neg p \).

Simple answerhood covers a fair amount of ground. But it clearly underdetermines aboutness. On the polar front, it leaves out the whole gamut of answers to polar questions that are weaker than \( p \) or \( \neg p \) such as conditional answers ‘If \( r \), then \( p \)’ (e.g. 10a) or weakly modalized answers ‘probably/possibly/maybe/possibly not \( p \)’ (e.g. (10b)). As far as wh-questions go, it leaves out quantificational answers (10c-g), as well as disjunctive answers. These missing class of propositions, are pervasive in actual linguistic use:

(10) a. Christopher: Can I have some ice-cream then?
   Dorothy: you can do if there is any. (BNC, KBW)

b. Anon: Are you voting for Tory?
   Denise: I might. (BNC, KBU, slightly modified)

c. Dorothy: What did grandma have to catch?
   Christopher: A bus. (BNC, KBW, slightly modified)

d. Rhiannon: How much tape have you used up?
   Chris: About half of one side. (BNC, KBM)

e. Dorothy: What do you want on this?
   Andrew: I would like some yogurt please. (BNC, KBW, slightly modified)

f. Elinor: Where are you going to hide it?
   Tim: Somewhere you can’t have it.(BNC, KBW)

g. Christopher: Where is the box?
   Dorothy: Near the window. (BNC, KBW)

One straightforward way to enrich simple answerhood is to consider the relation that emerges by closing simple answerhood under disjunction. Ginzburg (1995a); Ginzburg & Sag (2000) show that aboutness as defined in (11) seems to encompass the various classes of propositions exemplified in (10).

(11) \( p \) is About \( q \) iff \( p \) entails a disjunction of simple answers to \( q \).

Answerhood in the aboutness sense is clearly distinct from a highly restricted notion of answerhood, that of being a proposition that resolves or constitutes exhaustive information about a question. This latter sense of answerhood, which is restricted to true propositions, has been explored in great
detail in the formal semantics literature, since it is a key ingredient in ex-
plaining the behaviour of interrogatives embedded by resolutive predicates
such as ‘know’, ‘tell’ and ‘discover’. We will not discuss this here but refer the
reader to Ginzburg [2012].

Many queries are responded to with a query. A large proportion of these
are clarification requests, to be discussed in section 6. But in addition to these,
there are query responses whose content directly addresses the question posed,
as exemplified in (12):

(12) a. A: Who murdered Smith? B: Who was in town?
b. A: Who is going to win the race? B: Who is going to participate?
c. Carol: Right, what do you want for your dinner?
   Chris: What do you (pause) suggest? (BNC, KbJ)
d. Chris: Where’s mummy?
   Emma: Mm?
   Chris: Mummy?
   Emma: What do you want her for? (BNC, KbJ)

There has been much work on relations among questions within the frame-
work of Inferential Erotetic Logic (IEL) (see e.g. Wiśniewski [2001, 2003]),
yielding notions of q(uestion)–implication. From this a natural hypothesis can
be made about such query responses, as in (13a). A related proposal, first
articulated by Carlson [1983], is that they are constrained by the semantic
relations of dependence, or its converse influence.

(13) \( q_2 \) influences \( q_1 \) iff any proposition \( p \) such that \( p \) Resolves \( q_2 \), also
satisfies \( p \) entails \( r \) such that \( r \) is About \( q_1 \).

Its intuitive rationale is this: discussion of \( q_2 \) will necessarily bring about
the provision of information about \( q_1 \). The actual characterization of query
responses is complex, both empirically and theoretically, for a detailed account
using TTR see Lupkowski & Ginzburg [2013].
On the approach developed in KoS analysis of dialogue is formulated at a level of information states, one per conversational participant. Each information state consists of two ‘parts’, a private part and the dialogue gameboard that represents information that arises from publicized interactions. For recent psycholinguistic evidence supporting this partition see (Brown-Schmidt et al. 2008).

Information states are records of the type given in (14a). For now we focus on the dialogue gameboard. The type of dialogue gameboards is given in (14b) — the spkr, addr fields allow one to track turn ownership, Facts represents conversationally shared assumptions, Moves and Pending represent, respectively, lists of moves that have been grounded or are as yet ungrounded, QUD tracks the questions currently under discussion:

\[(14) \ a. \ \text{TotalInformationState} \ (TIS) =_{\text{def}} [\text{dialoguegameboard} : DGB ] \\
\quad \quad b. \ DGB \ (\text{provisional definition}) =_{\text{def}} \begin{bmatrix}
\text{spkr} & : \text{Ind} \\
\text{addr} & : \text{Ind} \\
\text{utt-time} & : \text{TimeInt} \\
\text{c-utt} & : \text{addressing(spkr,addr,utt-time)} \\
\text{Facts} & : \{\text{Prop}\} \\
\text{Pending} & : [\text{LocProp}] \\
\text{Moves} & : [\text{LocProp}] \\
\text{QUD} & : \text{poset(} \text{Question} \text{)}
\end{bmatrix}\]

Our job as dialogue analysts is to construct a theory that will explain how conversational interactions lead to observed conversational states of type DGBTtype. Let us consider how an initial conversational state looks, that is the state as the first utterance of the dialogue is made: initially no moves have been made and no issues introduced, so a dialogue gameboard will be of the type in (15):

\[(15) \begin{bmatrix}
\text{spkr} & : \text{Ind} \\
\text{addr} & : \text{Ind} \\
\text{utt-time} & : \text{TimeInt} \\
\text{c-utt} & : \text{addressing(spkr,addr,utt-time)} \\
\text{Facts} & =\{\} : \{\text{Prop}\} \\
\text{Pending} & =[] : [\text{LocProp}] \\
\text{Moves} & =[] : [\text{LocProp}] \\
\text{QUD} & =\{\} : \text{poset(} \text{Question} \text{)}
\end{bmatrix}\]

This allows us to construct a type corresponding to a lexical entry for a greeting word such as ‘hi’, as in (16). Here we assume that the definition of the type Sign in Section 3 has been modified to include a field for a dialogue game board:
This represents an extension of the Saussurean notion of sign where we not only take account of the signifier (‘s-event’) and the signified (‘synsem’) but also the context in which the signification takes place (here represented by ‘dgb’).

(16) \( \text{Sign} \setminus \)

\[
\begin{align*}
\text{s-event} & : \text{SEvent} \\
\text{synsem} & : \left[ \begin{array}{l}
\text{cat} : \text{Cat} \\
\text{cnt} : \text{Cnt}
\end{array} \right] \\
\text{dgb} & : \text{DGB}
\end{align*}
\]

Here, as before in our discussion of questions, \( r_{ds} \) is the described situation as determined by the context. The use of ‘\( \uparrow \)’ in the ‘sit-type’-field is a convenient informal notation for paths occurring in a record type embedded within a larger record type but not lying on a path in that record type. It indicates that the path is to be found in the next higher record type. It clears up an ambiguity that arises because we are using the notation that does not make explicit the dependent types that are being used as discussed on p. 5.

How do we specify the effect of a conversational move? The basic units of change are mappings between dialogue gameboards that specify how one gameboard configuration can be modified into another on the basis of dialogue moves. We call a mapping between DGB types a conversational rule. The types specifying its domain and its range we dub, respectively, the pre(conditions) and the effects, both of which are supertypes of the type \( \text{DGB} \). A conversational rule that enables us to explain the effect a greeting, the initial conversational move, has on the DGB is given in (17). It is a record type which contains two fields. The ‘pre(condition)’-field is for a dialogue gameboard of a certain type and the ‘effects’-field provides a type for the updated gameboard. The precondition in this example requires that both Moves and QUD
are empty; the sole effect is to push the proposition associated with hi onto the list in the ‘moves’-field.

\begin{equation}
\begin{aligned}
\text{pre:} & DGB \land \\
spkr: & Ind \\
addr: & Ind \\
utt-time: & TimeInt \\
\text{moves:} & [] : \text{[Prop]} \\
\text{qud:} & \{\} : \text{poset(}\text{Question}\text{)} \\
\text{effects:} & \text{sit}\overset{r_{ds}}{=} \text{[}e:\text{greet} \text{(pre.spkr, pre.addr, pre.utt-time)}\text{]} \text{[pre.moves: \{}\text{Prop}\text{\} : \text{RecType}]} \\
\end{aligned}
\end{equation}

(17)

The form for update rules proposed here is thus

\begin{equation}
\begin{aligned}
\text{pre:} & T_1 \\
\text{effects} = & T_2 : \text{RecType} \\
\end{aligned}
\end{equation}

An agent who believes that they have a current state \(s\) of type \(T_1\), that is, whose hypothesis about the current state is that it belongs to type \(T\) such that \(T \sqsubseteq T_1\), can use \(s\) to anchor \(T_2\) to obtain \(T_2[s]\) and then use asymmetric merge to obtain a type for the new state: \(T \bigvee T_2[s]\).

\begin{equation}
\text{Ask QUD–incrementation}
\end{equation}

(18) says that given a question \(q\) and \(\text{ASK}(A,B,q)\) being the LatestMove, one can update QUD with \(q\) as QUD–maximal.
QSPEC can be thought of as a ‘relevance maxim’: it characterizes the contextual background of reactive queries and assertions. (19) says that if \( q \) is QU–maximal, then subsequent to this the next move is constrained to be \( q \)-specific (Ginzburg (2012)), either About \( q \) (a partial answer) or a question on which \( q \) depends. Moreover, this move can be held by either of the speech event participants. The constraint in (19) involves merging a constraint concerning the information about QU and Moves with a constraint entitled TurnUnderSpec, which merely specifies that the speaker and addressee of the effects are distinct and drawn from the set consisting of preconds speaker and addressee:

(19) a. QSPEC

\[
\begin{align*}
\text{pre} : & \quad \text{qud.} = \langle q, Q \rangle : \text{poset(\text{Question})} \\
\text{effects} : & \quad \text{TurnUnderSpec} \land \\
& \quad \left[ \begin{array}{l}
\text{r} : \text{Prop} \lor \text{Question} \\
\text{R} : \text{IllocRel} \\
\text{LatestMove} = R(\text{spkr}, \text{addr}, \text{r}) : \text{IllocProp} \\
\text{c1} : \text{About}(r, q) \lor \text{Depend}(q, r)
\end{array} \right]
\end{align*}
\]

b. TurnUnderSpec = 

\[
\begin{align*}
\text{PrevAud} = \{ \text{pre.spkr, pre.addr} \} : \{ \text{Ind} \} \\
\text{spkr} : \text{Ind} \\
c1 : \text{member}(\text{spkr}, \text{PrevAud}) \\
\text{addr} : \text{Ind} \\
c2 : \text{member}(\text{addr}, \text{PrevAud}) \\
\land \text{addr} \neq \text{spkr}
\end{align*}
\]

QSPEC involves factoring out turn taking from the assumption that A asking \( q \) means B answering it. In other words, the fact that A has asked \( q \) leaves underspecified who is to address \( q \) (first or at all). This is justified by self-answering data such as the initial example we considered in the introduction (1), as well as (20a,b), where the querier can or indeed needs to keep the turn, as well as multi-party cases such as (20c) where the turn is multiply distributed:
(20)

a. Vicki: When is, when is Easter? March, April? (BNC, KC2)

b. Brian: you could encourage, what’s his name? Neil. (BNC, KSR)

6 Unifying metacommunicative and illocutionary interaction

Establishing that the most recent move has been understood to the satisfaction of the conversationalists, has come to be known as *grounding*, following extensive empirical work by Herb Clark and his collaborators ([Clark & Schaefer (1989); Clark & Wilkes-Gibbs (1986); Clark (1996)]). One concrete task for a dialogical theory is to account for the potential for and meaning of acknowledgement phrases, as in (21), either once the the utterance is completed, as in (21a), or concurrently with the utterance as in (21b):

(21) a. Tommy: So Dalmally I should safely say was my first schooling. Even though I was about eight and a half. Anon 1: Mm. Now your father was the the stocker at Tormore is that right? (British National Corpus (BNC), K7D)

b. A: Move the train . . .
   B: Aha
   A: . . . from Avon . . .
   B: Right
   A: . . . to Danville. (Adapted from the Trains corpus)

An additional task is to characterize the range of (potential) presuppositions emerging in the aftermath of an utterance, whose subject matter concerns both content and form:

(22) a. A: Did Mark send you a love letter?

b. B: No, though it’s interesting that you refer to Mark/my brother/our friend

c. B: No, though it’s interesting that you mention sending

d. B: No, though it’s interesting that you ask a question containing seven words.

e. B: No, though it’s interesting that the final two words you just uttered start with ‘I’

Developing a semantic theory that can fully accommodate the challenges of grounding is far from straightforward. A more radical challenge, nonetheless, is to explicate what goes on when an addressee cannot ground her interlocutor’s utterance. More radical because this ultimately leads to seemingly radical conclusions of an intrinsic semantic indeterminacy: in such a situation the public context is no longer identical for the interlocutors—the original speaker can carry on, blissfully unaware that a problem exists, utilizing a ‘grounded context’, whereas if the original addressee takes over the context is shifted to one which underwrites a clarification request. This potential context-splitting is illustrated in (23), originally discussed in ([Ginzburg (1997)]). (23) illustrates that the contextual possibilities for resolving the fragment ‘Bo?’ are distinct for the original speaker A and the original addressee B. Whereas there is one common possibility, the short answer reading, only B has the two clarification request readings, whereas only A has a self-correction reading, albeit one that probably requires an additional elaboratory follow up:
(23)

a. A: Who does Bo admire? B: Bo?
   Reading 1 (short answer): Does Bo admire Bo?
   Reading 2 (clausal confirmation): Are you asking who BO (of all people) admires?;
   Reading 2 (intended content ): Who do you mean ‘Bo’?

b. A: Who does Bo admire? Bo?
   Reading 1 (short answer): Does Bo admire Bo?
   Reading 2 (self correction): Did I say ‘Bo’?

CRs can take many forms, as illustrated in (24):

(24)

a. A: Did Bo leave?
   b. Wot: B: Eh? / What? / Pardon?
   c. Explicit (exp) : B: What did you say? / Did you say ‘Bo’ / What do you mean ‘leave’?
   d. Literal reprise (lit): B: Did BO leave? / Did Bo LEAVE?
   e. Wh-substituted Reprise (sub): B: Did WHO leave? / Did Bo WHAT?
   g. Reprise Fragments (RF): B: Bo? / Leave?
   h. Gap: B: Did Bo . . . ?
   i. Filler (fil): A: Did Bo . . . B: Win? (Table I from Purver (2006))

Now, as (25a) indicates, a priori ANY sub-utterance is clarifiable, including function words like ‘the’, as in (25c). While the potential for repetition-oriented CRification clearly applies to all utterances and their parts, it is an open question whether this is true for semantically/pragmatically oriented CRification. For empirical studies on this see (Healey et al. (2003); Purver et al. (2003, 2006)).

(25)

a. Who rearranged the plug behind the table?
   c. A: Is that the shark? B: The? B: Well OK, A. (based on an example in the film Jaws.)

Integrating metacommunicative interaction into the DGB involves two additions to the picture we have had so far, one minor and one major. The minor addition, drawing on an early insight of CA, is that repair can involve ‘putting aside’ an utterance for a while, a while during which the utterance is repaired. The ‘pending’-field in the dialogue gameboard is used for this. Note that this field contains a list of locutionary propositions. Most work on (dialogue) context to date involves reasoning and representation solely on a semantic/logical level. But if we wish to explicate MCI, then we cannot limit ourselves in this way.
If \( p : \text{LocProp} \), the relationship between \( p . \text{sit} \) and \( p . \text{sit-type} \) can be utilized in providing an analysis of grounding/CRification conditions:

(26)

a. Grounding: \( p \) is true: the utterance type fully classifies the utterance token.

b. CRification: \( p \) is false, either because \( p . \text{sit-type} \) is weak (e.g. incomplete word recognition) or because \( u \) is incompletely specified (e.g. incomplete contextual resolution—problems with reference resolution or sense disambiguation).

In principle one could have a theory of CRification based on generating all available CRs an utterance could give rise to. But in practice, as the data in (25) showed us, there are simply too many to be associated in a ‘precompiled’ form with a given utterance type.

Instead, repetition and meaning–oriented CRs can be specified by means of a uniform class of conversational rules, dubbed Clarification Context Update Rules (CCURs) in (Ginzburg (2012)). Each CCUR specifies an accommodated MaxQUD built up from a sub-utterance \( u1 \) of the target utterance, the maximal element of Pending (MaxPending). Common to all CCURs is a license to follow up MaxPending with an utterance which is co-propositional with MaxQud. (27) is a simplified formulation of one CCUR, Parameter identification, which allows \( B \) to raise the issue about \( A \)'s sub-utterance \( u \): what did \( A \) mean by \( u \)?

(27) Parameter identification:

\[
\begin{array}{l}
\text{max\_pending : LocProp} \\
\text{rst\_pending : [LocProp]} \\
\text{u : Sign} \\
\text{cu : member(u,max\_pending.sit.synsem.constits)} \\
\text{latest\_move : LocProp} \\
\text{rst\_moves : [LocProp]} \\
\text{spkr} : \text{Ind} \\
\text{pending} = \text{[max\_pending\_pending]} : \text{[LocProp]} \\
\text{moves} = \text{[latest\_move\_rst\_moves]} : \text{[LocProp]} \\
\text{qud} : \text{[Question]} \\
\text{e : mean(\text{[\text{spkr},\text{pre}\_u,\text{cnt}])})}$
\end{array}
\]

Parameter Identification (27) underpins CRs such as (28b–28c) as follow-ups to (28a). We can also deal with corrections, as in (28d).

(28) a. A: Is Bo here?

  b. B: Who do you mean ‘Bo’?

  c. B: Bo? (= Who is ‘Bo’?)

  d. B: You mean Jo.
7 Traditional semantic concerns in a dialogue perspective

In this section we will discuss two traditional concerns in semantics, negation and quantification, and show that we get a rather different view of them when we consider dialogue phenomena relating to them.

7.1 Negation

The classical view of negation is that it is a truth functional connective that maps true to false and false to true. In this section, which contains revised material from Cooper & Ginzburg (2011a,b), we will suggest an alternative view: that negation is used to pick out a negative situation type. It is crucial for this proposal to work that we are able to distinguish between positive and negative types in a way that is not possible on the standard approaches to “truth-value flipping” negation.

Consider the uses of no in the following (made-up) dialogue and the glosses given after them in square brackets.

Child approaches socket with nail
Parent: No. [“Don’t put the nail in the socket.”]
Do(#n’t) you want to be electrocuted?
Child: No. [“I don’t want to be electrocuted.”]
Parent: No. [“You don’t want to be electrocuted.”]

The first use of no does not relate back to any previous linguistic utterance but rather to an event which is in progress. The parent has observed the first part of the event and predicted a likely conclusion (as in the example of the game of fetch discussed in Section 2). The parent wishes to prevent the completion of the event, that is, make sure that the predicted complete event type is not realized. We claim that the central part of the meaning of negation has to do with the non-realization of some positive situation type (represented by a negative situation type), rather than a switching of truth values as on the classical logical view of negation. We see this again in the second use of no in response to the parent’s query whether the type child-wants-to-be-electrocuted is realized. The child’s negative response asserts that the type is not realized. The third utterance of no agrees with the previous assertion, namely this asserts agreement that the type is (or should be) empty. A naive application of the classical view of negation as a flipping of truth values might say that no always changes the truth-value of the previous assertion. This would make the wrong prediction here, making the parent disagree with the child. Our view that negation has to do with a negative situation type means that it will be used to disagree with a positive assertion and agree with a negative assertion, which seems to be how negation works in most, if not all, natural languages.
Another important fact about this dialogue is the choice of the parent’s question. The positive question is appropriate whereas the negative question would be very strange, suggesting that the child should want to be electrocuted. The classical view of negation as truth value flip has led to a view that positive and negative questions are equivalent (Hamblin 1973; Groenendijk & Stokhof 1997). This derives from a view of the contents of questions as the sets of propositions corresponding to their answers. While positive and negative questions do seem to have the same possible answers it appears that the content of the question should involve something more than the set of answers. The distinction between positive and negative questions was noted for embedded questions by Hoepelman (1983) who noted the following example:

The child wonders whether 2 is even.
The child wonders whether 2 isn’t even. (There is evidence that 2 is even)

Hoepelman’s observation is that the same kind of inference as we noticed with the negative version of the parent’s question about electrocution. That is, there is a suggestion that there is reason to believe the positive, that the type is realized. This kind of inference is not limited to negative questions but seems to be associated with negation in general. Fillmore (1985) notes the following examples

Her father doesn’t have any teeth
#Her husband doesn’t have any walnut shells
Your drawing of the teacher has no nose/#noses
The statue’s left foot has no #toe/toes

The examples marked with # sound strange because they are contrary to our expectations. We in general expect that people have teeth but not walnut shells, a nose but not several noses and several toes but not just a single toe. Fillmore discusses this in terms of frames. We would discuss this in terms of resources we have available. We can, however, create the expectations by raising issues for discussion within the dialogue thus creating the necessary resources locally:

A: My husband keeps walnut shells in the bedroom.
B: Millie’s lucky in that respect. Her husband doesn’t have any walnut shells.

This discussion points to a need to distinguish between positive and negative propositions based on positive and negative situation types. We have given two reasons for this:

- The content of no is different depending on whether it is used in a response to a negative or positive proposition
- The raising of a contrary expectation occurs only with negative assertions or questions

A third reason which has been discussed in the literature (recently by Farkas & Roelofsen ms) is that some languages have different words for yes depending on positive and negative propositions.

A: Marie est une bonne étudiante
   Marie is a good student
B: Oui / #Si.
   Yes / Yes (she is)
A: Marie n’est pas une bonne étudiante
   Marie isn’t a good student
B: #Oui / Si.
   Yes / Yes (she is)

In French the word oui is used to agree with a positive proposition and the word si is used to disagree with a negative proposition. Similar words exists in other languages such as German (ja/doch) and Swedish (ja/jo).
How do we know that the distinction between positive and negative propositions is a semantic distinction rather than a syntactic distinction depending on how the propositions are introduced? There are lots of ways of making a negative sentence, by using various negative words such as *not*, *no*, *none*, *nothing*. In French you have there are discontinuous constructions *ne...pas*/point/rien corresponding to “not/not at all/nothing”. However, in these constructions the *ne* can be omitted. Thus both of the following are possible: *je n’en sais rien/ j’en sais rien* (“I know nothing about it”). In Swedish there are two words for *not* which are stylistic variants: *inte, ej* The generalization that allows us to recognize all these morphemes or constructions as “negations” is the semantic property they share: namely that they introduce negative propositions.

On the traditional truth-value flipping view of negation it is hard to make this semantic distinction. For example, in a possible worlds semantics a proposition is regarded as a set of possible worlds – the set of worlds in which the proposition is true. On this view the negation of a proposition is the complement of that set of worlds belonging to the proposition. There is no way of distinguishing between “positive” and “negative” sets of possible worlds. However, on a type theoretic approach the distinction can be made in a straightforward manner.

The account of negation we give here is slightly different to that given in Cooper & Ginzburg (2011a,b) and as a consequence the definitions are slightly more elegant and intuitive. We introduce negative types by the clause:

If $T$ is a type then $\neg T$ is a type

Because types are intensional we can say that $\neg T$ is distinct not only from $T$ but also from any other type, without worrying that there might be an equivalent type that has the same witnesses. Thus simply by introducing a negative operation on types (represented by $\neg$) we distinguish negative types from positive ones. We can also introduce types of negative types. For example, we can introduce a type $\text{RecType}^-$ such that $T: \text{RecType}^-$ iff $T = \neg T$ and $T': \text{RecType}$. We can then define a type $\text{RecType}^-\uparrow$ whose witnesses are the closure of the set of negated record types under negation (in a similar manner to our definition of $\text{RecordType}^\uparrow$ on p. 14).
We can characterize witnesses for negative types by: $a : \neg T$ iff there is some $T'$ such that $a : T'$ and $T'$ precludes $T$. We say that $T'$ precludes $T$ iff either

1. $T = \neg T'$
2. $T, T'$ are non-negative and there is no $a$ such that $a : T$ and $a : T'$ for any models assigning witnesses to basic types and ptypes

It follows from these two definitions that (1) $a : \neg \neg T$ iff $a : T$ and that (2) $a : T \lor \neg T$ is not necessary ($a$ may not be of type $T$ and there may not be any type which precludes $T$ either). Thus this negation is a hybrid of classical and intuitionistic negation in that (1) normally holds for classical negation but not intuitionistic whereas (2), that is failure of the law of the excluded middle, normally holds for intuitionistic negation but not classical negation.

Nothing in these definitions accounts for the fact that $a : \neg T$ seems to require an expectation that $a : T$. One way to do this is to refine the clause that defines witnesses for negative types $a : \neg T$ iff there is some $T'$ such that $a : T'$ and $T'$ precludes $T$ and there is some expectation that $a : T$. There is some question in our minds of whether this addition should be included here or in some theory of when agents are likely to make judgements. What does it mean for there to “be some expectation”? We would like to relate this to the kind of functions we used to predict completions of events and which we also used for grammar rules, that is to dependent types. [Breitholtz (2010); Breitholtz & Cooper (2011)] use dependent types to implement Aristotelian enthymemes that is defeasible inference patterns. Such enthymemes could be either general or local context-specific resources that we have available to create expectations.

Finally, let us see how the techniques we have developed here could be combined with Austinian propositions.
The type of negative Austinian propositions can be defined as
\[
\begin{array}{l}
\text{sit} : \text{Rec} \\
\text{sit-type} : \text{RecType}^\dagger
\end{array}
\]

The type of positive Austinian propositions can be defined as
\[
\begin{array}{l}
\text{sit} : \text{Rec} \\
\text{sit-type} : \text{RecType}
\end{array}
\]

Thus we have a clear way of distinguishing negative and positive propositions.

7.2 Generalized quantifiers

Purver & Ginzburg (2004); Ginzburg & Purver (2008); Ginzburg (2012) introduce the Reprise Content Hypothesis (RCH):

RCH (weak) A fragment reprise question queries a part of the standard semantic content of the fragment being reprised.

RCH (strong) A fragment reprise question queries exactly the standard semantic content of the fragment being reprised.

They use this to motivate a particular view of the semantics of quantified noun-phrases which is based on witness sets rather than families of sets as in the classical treatment. Cooper (2010, 2013) argues for combining a more classical treatment with their approach. We summarize the argument here.
In terms of TTR, a type corresponding to a “quantified proposition” can be regarded as

\[
\begin{align*}
\text{restr : } & Ppty \\
\text{scope : } & Ppty \\
q & : q(\text{restr,scope})
\end{align*}
\]

The third field represents a quantificational ptype of the form \(q(\text{restriction,scope})\) an example of which would be every(\(\lambda r: [x: \text{Ind}\), \([c:\text{dog}(r.x)]\), \(\lambda r: [c:\text{run}(r.x)]\))

that is, ‘every’ is a predicate which holds between two properties, the property of being a dog and the property of running. As an example, suppose we want to represent the record type which is the content of an utterance of A thief broke in here last night. For convenience we represent the property of being a thief as thief and the property corresponding to broke in here last night as bihn. Then the content of the sentence can be:

\[
\begin{align*}
\text{restr='thief' : } & Ppty \\
\text{scope='bihn' : } & Ppty \\
\exists & : \exists(\text{restr,scope})
\end{align*}
\]

We can relate this proposal back to classical generalized quantifier theory, as represented in Barwise & Cooper (1981). Let the extension of a type \(T\), \([\downarrow T]\), be the set \(\{a \mid a : T\}\), the set of witnesses for the type. Let the \(P\)-extension of a property \(P\), \([\downarrow P]\), be the set

\(\{a \mid \exists r: [x: \text{Ind} \land r.x = a \land [\downarrow P(r)] \neq \emptyset]\}\)

that is, the set of objects that have the property. We say that there is a constraint on models such that the type \(q(P_1, P_2)\) is non-empty iff the relation \(q^*\) holds between \([\downarrow P_1]\) and \([\downarrow P_2]\), where \(q^*\) is the relation between sets corresponding to the quantifier in classical generalized quantifier theory. For example:

- some\((P_1, P_2)\) is non-empty (that is, “true”) just in case \([\downarrow P_1] \cap [\downarrow P_2] \neq \emptyset\)
- every\((P_1, P_2)\) is non-empty just in case \([\downarrow P_1] \subseteq [\downarrow P_2]\).
- many\((P_1, P_2)\) is non-empty just in case \(|[\downarrow P_1] \cap [\downarrow P_2]| > n\), where \(n\) counts as many.

The alternative analysis of generalized quantifiers that Purver and Ginzburg propose is based on the notion of witness set from Barwise & Cooper (1981). Here we will relate this notion to the notion of a witness for a type; that is something which is of that type. We have not yet said exactly what it is that is of a quantifier ptype \(q(P_1, P_2)\). One solution to this is to say that it is a witness set for the quantifier, that is

\(a : q(P_1, P_2)\) iff \(q^*\) holds between \([\downarrow P_1]\) and \([\downarrow P_2]\) and \(a = [\downarrow P_1] \cap [\downarrow P_2]\)

7 This appears to go against the intuition that we have introduced before that ptypes are types of situations. Ultimately we might wish to say that a witness for a quantifier type is a situation containing such a witness set, but we will not pursue this here.
This definition relies on the fact that all natural language quantifier relations are conservative (Peters & Westerståhl 2006), a notion which we can define as follows:

A quantifier \( q \) is conservative means \( \forall^* \) holds between \( \downarrow P_1 \) and \( \downarrow P_2 \)

just in case \( \forall^* \) holds between \( \downarrow P_1 \) and \( \downarrow P_1 \cap \downarrow P_2 \) (every person runs iff every person is a person who runs)

Armed with this we can define the type of (potential) witness sets for a quantifier relation \( q \) and a property \( P \), \( q^1(P) \), that is, witness sets in the sense of Barwise and Cooper:

\[ a : q^1(P) \text{ iff } a \subseteq \downarrow P \text{ and there is some set } X \text{ such that } q^* \text{ holds between } \downarrow P \text{ and } X \]

Using these tools we present a modified version of Ginzburg and Purver’s proposed analysis of most students left:

\[
\begin{array}{l}
\text{q-params:} [\text{restr}_i = \text{student}: P_{\text{pty}} \\
\text{cont :} c_{\text{most}} = q\text{-params.w:most} (\text{student.left})]
\end{array}
\]

In Cooper (2010) we presented the two analyses as in competition with each other, but we now think that there is advantage to be gained by putting the two together. Our way of combining the two analyses predicts two readings for the noun-phrase most students, a referential reading which makes the witness set be a q-parameter in Purver and Ginzburg’s analysis and a non-referential reading in which the witness set is incorporated in the content of the NP.

Given these types, what can a clarification address? Our claim is that the clarification must address something for which there is a path in the record type. In addition there appears to be a syntactic constraint that clarifications tend to be a “major constituent”, that is a noun-phrase or a sentence, rather than a determiner or a noun. In a referential reading there are three paths available: q-params.restr, q-params.w, and content. The first of these, the restriction, is dispreferred for syntactic reasons since it is normally expressed by a noun.
This leaves the witness and the whole NP content as possible clarifications. However, from the data it appears that the whole content can be expressed focusing either on the restriction or the quantifier relation. For non-referential readings only the whole content path is available.

Here we give one example of each kind of clarification from the data that Purver and Ginzburg adduce.

**Witness clarification**

Unknown: And er they X-rayed me, and took a urine sample, took a blood sample. Er, the doctor
Unknown: Chorlton?
Unknown: Chorlton, mhm, he examined me, erm, he, he said now they were on about a slide ⟨unclear⟩ on my heart. Mhm, he couldn’t find it.

BNC file KPY, sentences 1005–1008

**Content clarification with restriction focus**

Terry: Richard hit the ball on the car.
Nick: What car?
Terry: The car that was going past.

BNC file KR2, sentences 862–864

**Content clarification with quantifier relation focus**

Anon 2: Was it nice there?
Anon 1: Oh yes, lovely.
Anon 2: Mm.
Anon 1: It had twenty rooms in it.
Anon 2: Twenty rooms?
Anon 1: Yes.
Anon 2: How many people worked there?

BNC file K6U, sentences 1493–1499

Our conclusion is that a combination of the classical approach to generalized quantifier combined with a modification of the approach suggested by Purver and Ginzburg which adds a field for the witness provides correct predictions about clarifications if combined with a weak version of the reprise clarification hypothesis applied to the clarification. As far as we can see the clarification itself can follow the strong version of RCH as Purver and Ginzburg propose.
8 Grammar in Dialogue

8.1 Non-Sentential utterances

The basic strategy adopted in KoS to analyze NSUs is to specify construction types where the combinatorial operations integrate the (surface) denotata of the fragments with elements of the DGB.

(29) \[
\text{Sign} \land \\
\begin{cases}
\text{s-event} : \left[ \text{phon} : \text{yes} \right] \\
\text{synsem} : \\
\quad \text{cat} = \text{adv} : \text{Cat} \\
\quad \text{cnt} = q_{\text{max}}(r_d) : \text{Prop}
\end{cases}
\]

Here \( q_{\text{max}} \) is a maximal element of \( \text{dgb.qud} \).
8.2 Dysfluencies

Dysfluencies are ubiquitous and observable in all but the briefest conversational interaction. Dysfluencies have been studied by researchers in CA (Schegloff et al. (1977)), in great detail by psycholinguists (e.g. Levelt (1983); Brennan & Schober (2001); Clark & FoxTree (2002)), and by computational linguists working on speech applications (e.g. Shriberg (1994)). To date, they have mostly been excluded from semantic analysis, primarily because they have been assumed to constitute low level ‘noise’, without semantic import.

In fact, dysfluencies participate in semantic and pragmatic processes such as anaphora, conversational implicature, and discourse particles, as illustrated in (30). In all three cases, the semantic process is dependent on the reparandum (the phrase to be repaired) as the antecedent:

(30) a. Peter was + { well } he was ] fired. (Example from Heeman & Allen (1999))
    b. A: Because I, [ [ [ any, + anyone, ] + any friend, ] + anyone | I give my number to is welcome to call me (Example from the Switchboard corpus) (implicature: ‘It’s not just her friends that are welcome to call her when A gives them her number’)
    c. From yellow down to brown - NO - that’s red. (Example from Levelt (1983))

They also provide a particularly natural example of self-addressed queries, queries where the intended responder is the original querier:

(31) a. Carol: Well it’s (pause) it’s (pause) er (pause) what’s his name? Bernard Matthews’ turkey roast. (BNC, KBJ)
    b. A: Here we are in this place, what’s its name? Australia.

Since they can occur at just about any location in a given utterance and their effect is local, dysfluencies provide strong motivation for an incremental semantics, that is, a semantics calculated on a word-by-word, left to right fashion (see e.g. Steedman (1999); Kempson et al. (2000)). Moreover, they require the content construction process to be non-monotonic, since initial decisions can be overridden as a result of self-repair.
(Ginzburg et al. (2012)) sketch how, given an incremental dialogue semantics, accommodating dysfluencies is a straightforward extension of the account discussed in section 6 for clarification interaction: the monitoring and update/clarification cycle is modified to happen at the end of each word utterance event, and in case of the need for repair, a repair question gets accommodated into QUD. Overt examples for such accommodation is exemplified in (31).

8.3 Conversational Genres

Psycholinguistic labs aside, all meaningful interaction occurs within a particular conversational genre / activity type / language game. As I emphasized above, this is the fundamental entity determining what drives a dialogue—what issues can and need to be discussed and also how such discussion will take place (in terms of constructions and lexica), though this latter aspect I cannot consider here.

A very basic issue is—how to classify a conversation into a genre? One way is by providing a description of an information state of a conversational participant who has successfully completed such a conversation. This is a reasonable way of doing things as long as the final state does not lose “significant” information concerning what took place during the conversation. On the view of contextual evolution described here the final state of a conversational participant will be a DGB of the type $DGB$.

At the end of a conversation QUD is empty\(^8\), but the issues that have been discussed during the conversation can be recovered by examining FACTS: we can introduce a simple refinement of $\text{FACTS update/QUD downdate}$ such that every acceptance leads to the recording not solely of the facts added but also which questions were resolved by these facts and downdated. We can track such question using a field labelled QNUD (Questions No longer Under Discussion)\(^9\). Final states of a conversation will, hence, be records of type $T$ for $T$ a subtype of the type $\text{GenreType}$, which may be identified as the general type of all conversational genres:

\[
\text{GenreType} = \text{def}\begin{cases}\\ \text{facts} : \{\text{Prop}\}\\ \text{qnud} : \{\text{Question}\}\\ \text{moves} : \{\text{Prop}\}\\ \end{cases}
\]

\(^8\) Or rather, in order to end a conversation CPs need to ensure QUD is empty.

\(^9\) Such information is also what underwrites presuppositions of resolvedness. Such presuppositions characterize the complements of fact embedding verbs that combine with interrogative clauses, as discussed in Ginzburg (1995b).
We started the paper by considering an extract from an actual BNC dialogue. We pointed to the variety of phenomena one needs to tackle in order to provide even a rudimentary analysis of the example. We indicate very briefly how the framework sketched in the paper and detailed in works referenced therein allows one to develop accounts of the various phenomena:

- **NSUs:** these are analyzed using the DGB-driven context exemplified in section 8.1.
- **Dysfluencies** are handled using conversation rules of a similar form to Clarification Requests and, more generally, to general conversational rules; this requires adopting an incremental perspective for grammar (REFS).
- **Self answering:** this possibility is a consequence of factoring turn taking away from illocutionary specification, as in the conversational rule QSPEC.
- **Misunderstanding:** this is accommodated by (i) associating different DGBs per conversational participants, (ii) characterizing the grounding/CR conditions of utterances using locutionary propositions (propositions constructed from utterance types/tokens)
- **Multilogue** involves scaling up of 2-person conversational rules; main differences: communal grounding/acceptance, turn taking, . . . (See Ginzburg & Fernández (2003); Ginzburg (2012))

Possible worlds semantics has intrinsic problems, ones Montague was aware of when he first used it in his seminal papers in the 1970s. We have seen how TTR provides an ontology which can be used to solve doxastic puzzles (propositions) and dialogical puzzles (negation).

TTR allows one to synthesize \( \lambda \)-calculus driven and unification–based synsem interfaces:

- Robust meaning/context/content relations (section 6) [to be added in in next draft]
- Generalized Quantifiers (section 7.2)
- Questions (section 4.1)
- Utterance types (for metacommunicative interaction) (sections 3 and 6)

Ongoing work using TTR suggests it can be used to underpin work on significant problems in Cognitive Science. This includes:

- Parsing and incremental interpretation (refs)
- Semantics for spatial descriptions (reference to Simon’s paper)
- Integration of vector and logical representations (reference to Staffan’s paper)
- Probabilistic Semantics (Cooper/Lappin paper)
References


Cooper, Robin (2010), Generalized quantifiers and clarification content, in Lupkowski & Purver (2010).

Cooper, Robin (2012), Type theory and semantics in flux, in Ruth Kempson, Nicholas Asher, & Tim Fernando (eds.), Handbook of the Philosophy of Science, Elsevier BV, volume 14: Philosophy of Linguistics, (271–323), general editors: Dov M. Gabbay, Paul Thagard and John Woods.

Cooper, Robin (2013), Clarification and generalized quantifiers, Dialogue and Discourse.


Coquand, Thierry, Randy Pollack, & Makoto Takeyama (2004), A logical framework with dependently typed records, *Fundamenta Informaticae* XX:1–22.

Farkas, Donka & Floris Roelofsen (ms), Polarity particles in an inquisitive discourse model, Manuscript, University of California at Santa Cruz and ILLC, University of Amsterdam.


Ginzburg, Jonathan & Matt Purver (2008), Quantification, the reprise content hypothesis, and type theory, in Lars Borin & Staffan Larsson (eds.), *From Quantification to Conversation*, University of Gothenburg, University of Gothenburg, Gothenburg.


Martin-Löf, Per (1984), Intuitionistic Type Theory, Bibliopolis, Naples.
Michaelis, Laura A. (2009), Sign-based construction grammar, in The Oxford Handbook of Linguistic Analysis, Oxford University Press.


Purver, Matthew, Jonathan Ginzburg, & Patrick Healey (2006), Lexical categories and clarificational potential, revised version under review.


Shieber, Stuart (1986), An Introduction to Unification-Based Approaches to Grammar, CSLI Publications, Stanford.


