Bridging as Coercive Accommodation

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1 Introduction

[Van der Sandt, 1992] introduces [Lewis, 1979]' notion of *accommodation* in Discourse Representation Theory [Kamp and Reyle, 1993] as a tool to account for gaps in the discourse. His theory of presupposition projection takes presuppositions to behave like anaphora. Anaphoric expressions normally are linked to antecedents that have previously been established in the discourse. If example (1) would appear in a context where no *king of France* is present – hence no antecedent is available – then Van der Sandt's algorithm *accommodates* the existence of a king of France.

(1) When I give a party, the king of France always attends it.

This is different from the situation where a definite description can be *linked* to an antecedent that was previously introduced by an indefinite description, as in (2). There is no need to accommodate an antecedent, because there is already a suitable candidate available.

(2) When I invite a celebrity, the celebrity never comes.

Example (3) however is slightly different. There is no actual antecedent for the anaphoric expression *the barkeeper*, but because of *a bar*, there isn't really a problem, apparently there is some implicit antecedent. Van der Sandt's projection algorithm fails to make this implicit link, and accommodates the existence of *a barkeeper* to the global context, in fact no theory on presupposition that we know of can deal with these[1].

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[1]The closest comes probably Beaver's dynamic theory of presupposition [Beaver, 1993].

(3) When I go to a bar, the barkeeper always throws me out.

Contrasting (3) with (4) makes our point even clearer; this sentence sounds truly infelicitous. The hearer tries to somehow link this *barkeeper* with familiar information, and fails.

(4) ? When I go to a playground, the barkeeper always throws me out.

A bar provides sufficient information to license *the barkeeper*, but in *a playground* there is nothing that can establish such a link. Making a link between the new discourse referent (i.e. *the barkeeper*) to the network of discourse referents that is already established, is called *bridging* ([Clark, 1975], [Heim, 1982]). Definite descriptions that can be bridged to existing information do not need the accommodation of new referents; example (1) requires accommodation, but (3) can be solved with mere bridging. An adequate theory of presupposition obviously needs a serious explanation of bridging to account for the projection problem of presupposition.

To account for these phenomena, we borrow from [Pustejovsky, 1991] and compare *bridging* with *coercion*. Pustejovsky presents examples like (5):

(5) I would like to begin a new book tonight.

Here, too, some information is missing: *begin* implies some event, but *a new book* is an artifact. The fact that the speaker should be interpreted as *beginning to read the book*, or – if he is a writer – *to write* one, is motivated by what we know about *book*. Pustejovsky claims that such information should be considered lexical knowledge of the noun, which is represented in a so-called *qualia structure*. Based on this information, arguments of improper types can be *coerced* to proper ones. We will see how a similar approach can be followed to account for *bridging*.

In section 2 we will present Pustejovsky's ideas in more detail, explaining concepts like *coercion* and *qualia structure*. In Pustejovsky's work these ideas only get applied on the sentence level. Section 3 will show how the ideas of Van der Sandt and Pustejovsky fit together very nicely, even complementing each other and we will show that *bridging* operates intra- as well as inter-sentential. In section 3.4 we will present some examples of *linking*, *bridging* and *accommodation*, and in section 4 we will discuss the notion of functional composition and coercion in this model.

2 Qualia Structure and Coercion

2.1 Qualia Structure

In [Pustejovsky, 1991] and subsequent papers the notions of *coercion* and *qualia structure* have been introduced. Qualia structure can be seen as a set of lexical entailments. For instance, the word *book* entails at least the two events of *reading* and *writing* it, besides the knowledge that it consists of several separate parts, like the *cover*, *pages*, etc. Pustejovsky suggests four *qualia roles* to represent such knowledge: FORMAL, CONSTITUTIVE, TELIC and AGENTIVE. In [Pustejovsky, 1991] these have been defined as follows[2]:

- FORMAL: That which distinguishes the object within a larger domain.
- CONSTITUTIVE: The relation between an object and its constituents or proper parts.
- TELIC: Purpose and function of the object.
- AGENTIVE: Factors involved in the origin or "bringing about" of an object.

The exact structure of this kind of lexical semantic knowledge seems to be very intricate. Again for the same example, it is important for instance to realize that a *book* is at the same time a *physical object* and an *information container*. The first description considers the physical viewpoint, whereas the second defines the conceptual angle of what constitutes our idea of a *book*. What angle one takes (*physical object* or *information container*) has immediate consequences for the knowledge that is represented in the rest of the qualia structure. The composing parts of the physical side of a book (*pages*, *cover*, etc.) are different from those of the conceptual side (*title*, *sections*, *paragraphs*, etc.). The same goes for the representation of typical events a book is involved in. The physical 'quality' (qual) of a book can be *printed*, *typeset* or even *shelved*. The information 'quality' can be said to undergo the events of *reading*, *writing* as mentioned before. It is however undeniable that the two main qualities of book, along with all their entailments, are intimately related to each other and should be represented accordingly in one comprehensive (qualia) structure.

2.2 Coercion

The need for a rich lexical semantic knowledge representation like qualia structure becomes clear in considering sentences like (5) above, which is repeated here:

(6) I would like to begin a new book tonight.

As mentioned before, the verb *begin* expects an event here but has to settle for an *artifact* (book). We can now use the qualia structure of this *artifact* to infer some *event* that is entailed by it and which can stand in its place. This is an example of what Pustejovsky has called *metonymic reconstruction* [Pustejovsky, 1991] for cases where an interpretation can be inferred from some partial meaning of the word in question. In more general terms, anytime a word or phrase is not of the desired type[3] (like *artifact*, *event*, etc.) we are

[2]In more common AI-related terms we could rephrase them as: FORMAL - ISA, CONSTITUTIVE - PART-OF / HASA, TELIC - PURPOSE and AGENTIVE - CAUSE.

[3]Possibly this use of the term *type* is not appropriate and we should use *sort* instead. However, here we present the terms as they have been defined by [Pustejovsky, 1991].

allowed to *coerce* it into one of its entailments that is of the appropriate type, where the entailments are stored in its qualia structure. Another example of this is the following sentence:

(7) BMW announced a new model.

Here the verb *announce* is looking for a subject of type *animate* while only one of type *institute* is available. The qualia structure of any *institute* however should represent the fact that they are made up of people, which are *animate* entities. So, in this sentence we can infer that some human at the BMW company did the actual announcement.

This summarizes Pustejovsky's program as described in [Pustejovsky, 1991] and subsequent papers. In this paper we extend coercion with the notion of context, which seems not only a valid research topic but also desperately needed because of the restricted explaining power of coercion if context is not considered. Take for instance sentence (8) :

(8) John began a book.

Although above we assumed several times that one can infer *read* and *write* events from the qualia structure of *book* in order to make this sentence semantically well formed, this can only be a default approximation. We would need an actual context for this sentence to decide what event exactly should be inferred. Imagine for instance a dinner, organized by the LITERARY AND CULINARY SOCIETY, where all dishes are shaped in the form of books...[4]

This example is farfetched, but it may make the point more clear. We do not assume that the qualia structure of *book* should contain any reference to this particular example. It is important however to realize that any *artifact* entails by default a number of events in which it is engaged. In this particular context these events would be overruled.

[4] Still another problem concerning the lack of context is illustrated by the following examples where no argument at all is available for coercion to take place, *Monday* and *yesterday* are modifiers:

I propose Monday.
I began yesterday.

Pustejovsky (personal communication) has termed this loosely as *null coercion*, because although coercion should take place it cannot be executed properly. Taking context into account could be of help however to make the sentences sound more natural, as the following examples show:

Let's make an appointment. I propose Monday.
Let's play darts. I begin.

It seems that null coercion should coerce an anaphor which is of the required type. In both examples this would be event-type anaphors.

3 Bridging in DRT with Qualia Structure

This section shows how we deal with anaphora resolution in general, and particularly bridging, in a version of DRT which uses extensively *qualia* information. We define the language of Discourse Representation Structures (DRSs) of our extended DRT, show how resolution works, and finally give some detailed examples.

3.1 A Sketch of the Architecture

Basically, we extend Van der Sandt's theory of presupposition with the notion of bridging anaphora. In short, Van der Sandt views presupposition as anaphora with more descriptive content, and uses one and the same mechanism for dealing with both phenomena [Van der Sandt, 1992]. Anaphoric information can either be resolved to an antecedent that is available from discourse, or if no antecedent is found, be accommodated. We add a possibility of bridging to the resolution algorithm. The basic architecture of the system is:

1. parse sentence: result is a sentence-DRS
2. merge sentence-DRS with main-DRS
3. perform anaphora resolution

A *sentence-DRS* is a DRS with all anaphoric information unresolved, and is the result of a bottom-up driven semantic construction dependent on some syntactic structure. A sentence-DRS can be viewed as a sort of under-specified logical form with respect to anaphoric information. Special types of DRSs (α-DRSs) mark anaphoric information. The *main-DRS* is the DRS of the context interpreted so far. It is a *proper* DRS, i.e., a DRS with no unresolved anaphoric information. Proper DRSs can be interpreted as in standard DRT: they are *true* with respect to a certain model if they can be *embedded* in that model ([Kamp and Reyle, 1993]. Before we explain how anaphora resolution works we define DRSs and the merging operation.

3.2 Discourse Representation Structures

Let's introduce some terminology. Discourse markers are variables ranging over objects in the domain. Terms are either discourse markers or DRSs. Furthermore, we adopt a typed lambda-calculus for DRSs [Bos *et al.*, 1994; Muskens, 1993]. DRSs are defined as follows:

Definition 1. DRS
If U is a set of discourse markers, C is a set of DRS-Conditions, and $t_1,...,t_n$ terms, then $< U, C >$ is a DRS, $< U, C > \oplus < U', C' >$ is a DRS, λ $t_1,...,t_n$. $< U, C >$ is a DRS. Nothing else is a DRS.

Definition 2. DRS-Conditions
If x_1,..,x_n are discourse markers, P an n-place condition, K and K_1 DRSs, then $P(x_1,...,x_n)$, $x_1 = x_2$, $K \rightarrow K_1$, $\neg$ K, $K \vee K_1$, α:K, and Q:K are DRS-Conditions. Nothing else is a DRS-Condition.

The first five DRS-Conditions we already know from standard DRT [Kamp and Reyle, 1993] and need no further explanation. So called α-DRSs represent unresolved anaphoric information. DRSs that contain α-DRSs are therefore unresolved DRSs. Q-DRSs represent qualia structure, with Q_F for *formal*, Q_C for constitutive, Q_A for agentive and Q_T for telic. For notational purposes we use $\mathcal{Q}$ to represents a *set* of qualia-DRSs[5]. Now for merging:

Definition 3. Merging ($\oplus$).
$< U_1, C_1 > \oplus < U_2, C_2 >=< U_1 \cup U_2, C_1 \cup C_2 >$

The merge operation takes two DRSs and makes a union of the sets of discourse markers and a union of the sets conditions. Merging of DRSs is used both for constructing DRSs (cf. [Bos *et al.*, 1994]) and *coercive accommodation*.

The latter term brings us to the next definition. Qualia-information, represented in Q-DRSs is normally not accessible and does not affect the truth-conditions of a DRS. It is introduced in the lexicon and brought into discourse via the DRS bottom-up construction algorithm. If necessary, for example to play the role of antecedent, the qualia structure is put forward to the surface by a process we call *coercive accommodation*. It is defined as a function from DRSs to sets of DRSs:

Definition 4. Coercive Accommodation (CA).
$\textsc{ca}(< U, C >) = \{< U, C > \oplus \mathrm{K} \mid \mathrm{Q{:}K} \in C\}$

Note that CA is always local: it cannot accommodate qualia information which is embedded. Note also that we have defined CA only for DRS without lambda's: this will do for the purposes of this paper. Q-DRSs are also used for *type coercion*, which is discussed later on in this paper.

In DRT the structure of DRSs restricts the choice of possible antecedents of an anaphoric construction. For a discourse marker to be the antecedent for an anaphor, it must be *accessible* from the DRS which the anaphor is represented. To define accessibility of DRSs and discourse markers we first use the notion *subordination* between DRSs. We adopt the notation C(K) meaning the set of conditions of DRS (K), and U(K) meaning the set of discourse markers of K.

Definition 5. Subordination.
If K_1, K_2, and K_3 are DRSs, then K_2 is subordinated to K_1 (or K_1 subordinates

[5]As mentioned in section 2.1 on page 3, the distinction that is made in the formal role carries through in all other qualia roles. This could be represented by embedding Q_C, Q_A and Q_T in Q_F. This is beyond the scope of our paper.

K_2) if $K_1 \oplus K_2$, $K_1 \rightarrow K_2 \in C(K_3)$, $K_2 \rightarrow K_3 \in C(K_1)$, $\neg\, K_2 \in C(K_1)$, $K_2 \vee K_3 \in C(K_1)$, $K_3 \vee K_2 \in C(K_1)$, α:$K_2 \in C(K_1)$, Q:$K_2 \in C(K_1)$, and K_2 is subordinated to K_3 and K_3 is subordinated to K_1.

So, if x is a discourse marker and K_1 and K_2 are DRSs, and x is in the domain of K_1 ($x \in U(K_1)$), then x is accessible from K_2 if K_2 is subordinated to K_1.

3.3 Anaphora Resolution

Left to explain is how anaphora resolution works. We repeat for convenience that resolution can take place in three different ways:

1. resolution to an accessible, suitable discourse marker (*linking*)
2. resolution to coercively accommodated material of an accessible DRS (*bridging*)
3. accommodation of the anaphoric information to an accessible DRS (*accommodation*)

We introduced accessibility already, but haven't explained yet the notion of 'suitable' discourse marker, or better: suitable DRSs. Suitability is an extra constraint on the choice of antecedent. A DRS is suitable to another DRS if there is a way you find a match between discourse markers and conditions between both. More formally:

Definition 6. Suitability.
A DRS K_2 is m-suitable to DRS K_1 if there is a mapping m such that scope(m)=U(K_2) and for every x it is the case that $m(x) \in U(K_1)$ and there is a DRS K_3 such that $C(K_3) \subseteq C(K_1)$ if $U(K_3) = \{\, m(x) \mid x \in U(K_1)\}$.

We now introduce the heart of the system: anaphora resolution. This algorithm works as follows. All anaphoric information in the main-DRS (of course after merging it with the sentence-DRS of the last processed sentence) is resolved. This information is clearly marked because these are just our α-DRSs. Resolution either unifies this material with a suitable antecedent or accommodates it, and as a result, α-DRSs disappear. After resolving all α-DRSs, we are left with a proper-DRS, a DRS which is fully specified with respect to anaphoric information. This DRS is model-theoretically interpretable, as in standard DRT.

To describe the component, we use K_α to indicate anaphoric DRSs, and K_m for the main-DRS. Definition 7 describes a function that takes a certain main-DRS and a certain α-DRS from it, and returns a set of DRSs (since there could be more than one possible antecedent or accommodation site) with this α-DRS resolved. The output of this function can be fed back into the same function until all anaphoric information is resolved (all α-DRS have been consumed).[6]

[6]The order of which resolution of anaphoric structure takes place is important as well. We don't pay any attention to this, but see [Van der Sandt, 1992].

Definition 7. Anaphora Resolution.

$$
\begin{aligned}
\textsc{ar}(K_\alpha,K_m) &= \{\ K' \mid K' \in \textsc{link}(K_\alpha,K_m)\ \} \text{ iff } |\textsc{link}(K_\alpha,K_m)| > 0\\
&= \{\ K' \mid K' \in \textsc{bridge}(K_\alpha,K_m)\ \} \text{ iff } |\textsc{link}(K_\alpha,K_m)| = 0 \text{ and}\\
&\qquad |\textsc{bridge}(K_\alpha,K_m)| > 0\\
&= \{\ K' \mid K' \in \textsc{acc}(K_\alpha,K_m)\ \} \text{ iff } |\textsc{link}(K_\alpha,K_m)| = 0 \text{ and}\\
&\qquad |\textsc{bridge}(K_\alpha,K_m)| = 0
\end{aligned}
$$

Note that this definition prefers linking to bridging, and bridging to accommodation, which we assume is right. LINK, BRIDGE, and ACC are functions from the main DRS to sets of DRSs. We use DRSsubstitution to describe these operations ([K_1 / K_2] K_3 means that K_1 is substituted for K_2 in K_3).

Definition 8. Linking.

$\textsc{link}(K_\alpha,K_m) = \{\ [\ K_3\ /\ K_2\ ]\ K_m \mid K_\alpha$ is subordinated and m-suitable to K_1 & $\alpha{:}K_\alpha \in C(K_2)$ & $U(K_3)=U(K_2) \cup U(K_\alpha)$ & $C(K_3)=C(K_2)\text{-}\alpha{:}K\alpha \cup C(K_\alpha) \cup \{\ x=y \mid m(x)=y\ \}\ \}$

Definition 9. Bridging.

$\textsc{bridge}(K_\alpha,K_m) = \{\ K'_m \mid K_\alpha$ is subordinated K_4 & $K_1 \in \textsc{ca}(K_4)$ & m-suitable to K_1 & $\alpha{:}K_\alpha \in C(K_2)$ & $U(K_3)=U(K_2) \cup U(K_\alpha)$ & $C(K_3)=C(K_2)\text{-}\alpha{:}K\alpha \cup C(K_\alpha) \cup \{\ x=y \mid m(x)=y\ \}$ & $K'_m = [\ K_3\ /\ K_2\ ]\ K_m$ & $K'_m = [\ K_1\ /\ K_4\ ]\ K_m\ \}$

Definition 10. Accommodation.

$\textsc{acc}(K_\alpha,K_m) = \{\ K'_m \mid K_\alpha$ is subordinated to K_1 & $\alpha{:}K_\alpha \in C(K_2)$ & $U(K_3)=U(K_2)$ & $C(K_3)=C(K_2)\text{-}\alpha{:}K_\alpha$ & $K'_m=[\ K_1 \oplus K_\alpha\ /\ K_1\ ]\ K_m$ & $K'_m=[\ K_3\ /\ K_2\ ]\ K_m\ \}$

Accommodation has its limits. First, it shouldn't introduce free variables, and Van der Sandt introduces a number of acceptability rules for accommodation. These are briefly: resolution should not introduce contradictions and require a contribution to discourse. For more discussion on this issue the interested reader should consult [Van der Sandt, 1992].

3.4 Examples of Linking, Bridging and Accommodation

This section exemplifies the notions *linking*, *bridging*, and *accommodation*, which we introduced in the previous section. We will do this in view of the examples given in the introduction. For each of these examples we give the DRS with all anaphoric information unresolved, and the fully resolved derived after anaphora resolution as well. For reasons of clarity, only the relevant parts of the DRSs are deeply analyzed.

3.4.1 Linking

The first example involves simple linking between anaphor and antecedent. Consider the unresolved DRS of (2):

$$\boxed{\begin{array}{l} \\ \hline \boxed{\begin{array}{l} \text{x} \\ \hline \text{celebrity(x)} \\ \text{I-invite(x)} \end{array}} \rightarrow \boxed{\begin{array}{l} \\ \hline \alpha\text{:} \boxed{\begin{array}{l} \text{y} \\ \hline \text{celebrity(y)} \end{array}} \\ \text{never-comes(y)} \end{array}} \end{array}}$$

The definite description introduces an α-DRS for *the celebrity*, since this is presupposed information. Trying to link this anaphoric information is successful, since there is an accessible suitable discourse marker available. The result is the resolved DRS:

$$\boxed{\begin{array}{l} \\ \hline \boxed{\begin{array}{l} \text{x} \\ \hline \text{celebrity(x)} \\ \text{I-invite(x)} \end{array}} \rightarrow \boxed{\begin{array}{l} \text{y} \\ \hline \text{celebrity(y)} \\ \text{y=x} \\ \text{never-comes(y)} \end{array}} \end{array}}$$

This DRS can be read as: *If I invite a celebrity, he never comes.*

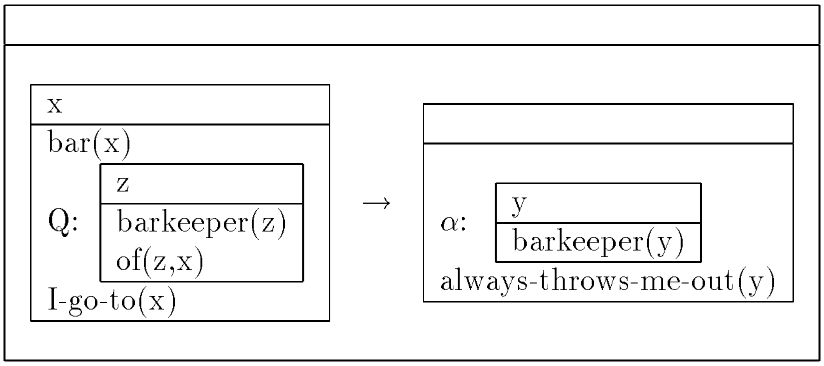
3.4.2 Bridging

Now for our bridging[7] example. The unresolved DRS of example (3) is (simplifying the Q-DRS for convenience):

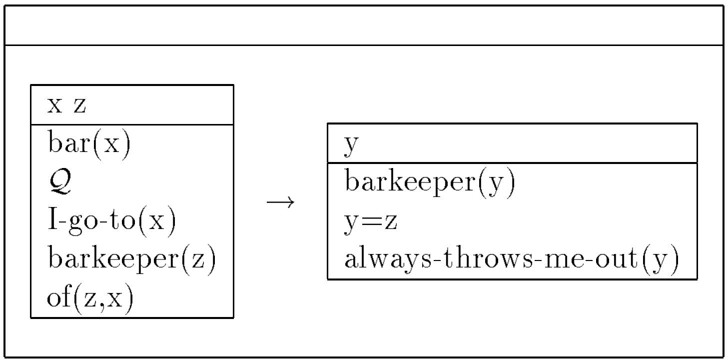
[7] Bridging does not seem to be the preferred option in the case of resolution of pronouns as the following examples show:

When I go to a bar, he always throws me out.
When BMW announced a new model, he looked very proud.

In both sentences a reading for 'he' can be found by linking to coercively accommodated material out of the Q-DRS from respectively *bar* and *BMW*, i.e. *a barkeeper* or *a spokesperson*. However they don't seem to be the preferred readings as has been shown by [McGlashan, 1992; Sanford and Garrod, 1981] for similar examples.



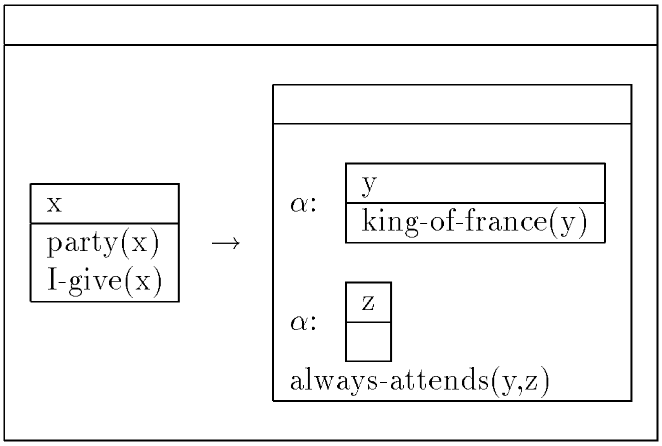
The presupposition trigger *the barkeeper* introduces the anaphoric information. Linking fails, the only available discourse marker is not suitable since the condition of anaphoric information does not match with it. Bridging is successful, though, yielding the resolved DRS:



This DRS does not assume a particular barkeeper that throws the speaker out, but a barkeeper that belongs to the bar the speaker goes to – the correct prediction.

3.4.3 Accommodation

Accommodation is our emergency case: *if everything fails, then accommodate.* This happens in cases like (1), which unresolved DRS is:



The pronoun represented by the discourse marker *z* can be linked to x. But we cannot link *the king of France* to some accessible discourse marker, nor is there a way to make bridging inference. The only possibility left is to accommodate the king:

$$\begin{array}{|l|}\hline \text{y} \\ \hline \text{king-of-france(y)} \\ \begin{array}{|l|}\hline \text{x} \\ \hline \text{party(x)} \\ \text{I-give(x)} \\ \hline \end{array} \quad \rightarrow \quad \begin{array}{|l|}\hline \text{z} \\ \hline \text{z=x} \\ \text{always-attends(y,z)} \\ \hline \end{array} \\ \\ \hline \end{array}$$

This DRS represents the reading: *there is a king of France, and if I give a party, he will attend it.* This is again the correct prediction.

4 Functional Composition and Coercion

4.1 Defining the notions

Functional Composition, including type coercion, is defined as follows, K_1 being the functor, K_2 the argument, and $\vec{\sigma}$ a sequence of terms such that $K_2(t)(\vec{\sigma})$ is a proposition:

Definition 11. Functional Composition ($\odot$).

$$\begin{aligned} K_1 \odot K_2 &= \lambda\, \vec{\sigma}.\ K_1(\lambda\ v.\ (K_2(v)(\vec{\sigma})))\ \text{iff } K_1 \text{ is of type } <\alpha,t> \text{ and v is of type } \alpha; \\ &= K_1 \odot K_3\ (\text{where } K_3 \in \textsc{tc}(K_2))\ \text{otherwise.} \end{aligned}$$

Clause one is like the functional composition rule (in [Bos *et al.*, 1994]). This rule has the nice property that it doesn't need type-shifting of arguments. It always binds the first argument position of the argument, and has functional application as a special case ($\vec{\sigma}$ is empty then). The second clause does the type coercion stuff (cf. [Pustejovsky, 1993]):

Definition 12. Type Coercion (TC).
$\textsc{tc}(K)=\{\ K' \odot K \mid K' \in \textsc{qa}(K)\ \}$

Definition 13. Qualia Access (QA).
$\textsc{qa}(K)=\{\ K_Q \mid Q{:}K_Q \in C(K) \text{ or } \textsc{qa}(K') \text{ where K' is a sub-DRS of K}\ \}$

Note that TC also works for arbitrarily deep embedded DRSs by use of the Qualia Access function. This is nice for quantified NPs like *every book*, where the qualia DRSs lexically introduced for *book* has been placed in the restrictor.

4.2 Some lexical entries

In this section we present some example lexical entries. In this paper we will only assign (a simplified) qualia structure to nouns[8], see **book**. Lexical entries can be abbreviated by their boldface notation – **write** stands for the semantic part of the lexical entry of *write*. We use small e,x,y and z for variables over type e (for entities, i.e. objects and events), capital P for DRS of type <e,t> (properties), and capital E for event-types (normally $< e, t >$).

$$\textbf{book}\text{: } \lambda z. \begin{array}{|l|}\hline z \\ \hline \text{book}(z) \\ Q_F\text{: } \begin{array}{|l|}\hline \\ \hline \text{info\_cont}(z) \\ \hline \end{array} \\ \\ Q_C\text{: } \begin{array}{|l|}\hline Z \\ \hline \text{sections}(Z) \\ \text{has}(z,Z) \\ \hline \end{array} \\ \\ Q_A\text{: } \textbf{write} \\ Q_T\text{: } \textbf{read} \\ \hline \end{array}$$

By introducing determiners (**a, the, every**) we account for the possibility to carry qualia structure through the derivation. Note the difference between these three determiners. The article *the* introduces an α-DRS since it is a presupposition trigger.

$$\textbf{a} \quad : \lambda\ P_1\ P_2. \begin{array}{|c|}\hline x \\ \hline \\ \hline \end{array} \oplus P_1(x) \oplus P_2(x)$$

$$\textbf{the} \quad : \lambda\ P_1\ P_2. \begin{array}{|l|}\hline \\ \hline \alpha\text{: } \begin{array}{|c|}\hline x \\ \hline \\ \hline \end{array} \oplus P_1(x) \\ \hline \end{array} \oplus P_2(x)$$

$$\textbf{every}\text{: } \lambda\ P_1\ P_2. \begin{array}{|l|}\hline \\ \hline \begin{array}{|c|}\hline x \\ \hline \\ \hline \end{array} \oplus P_1(x) \rightarrow P_2(x) \\ \hline \end{array}$$

The proper name **john** introduces an anaphoric DRS which is merged with the representation of its predicate. Proper names do *not* have qualia structure (see footnote earlier).

$$\textbf{john}\text{ : } \lambda\ P. \begin{array}{|l|}\hline \\ \hline \alpha\text{: } \begin{array}{|l|}\hline x \\ \hline \text{john}(x) \\ \hline \end{array} \\ \hline \end{array} \oplus P(x)$$

[8][Pustejovsky, 1995] assumes qualia structures for *all* categories.

The verbs **write** and **read** introduce event-types. Lambda-operators bind the variables that will fulfill the thematic roles *agent* and *theme*.

$$\textbf{write}: \lambda\ y\ x\ e. \quad \begin{array}{|l|}\hline \\ \hline \text{write(e)} \\ \text{agent(e,x)} \\ \text{theme(e,y)} \\ \hline \end{array}$$

$$\textbf{read}: \lambda\ y\ x\ e. \quad \begin{array}{|l|}\hline \\ \hline \text{read(e)} \\ \text{agent(e,x)} \\ \text{theme(e,y)} \\ \hline \end{array}$$

The aspectual verb **begin** expects something that expresses an event-type. We here simply treat it as a modifier, and ignore its further aspectual presuppositions.

Finally, tense **pres** applies to an event-type and binds off the event variable:the result is a DRS of type t, i.e. a DRS with no lambda variables.

$$\textbf{begin}\ \lambda\ E\ x\ e. \quad \begin{array}{|l|}\hline \\ \hline \text{begin(e)} \\ \hline \end{array} \quad \oplus\ E(x)(e)$$

$$\textbf{pres}: \lambda\ E. \quad \begin{array}{|l|}\hline \text{e} \\ \hline \text{now(e)} \\ \hline \end{array} \quad \oplus\ E(e)$$

4.3 A sample derivation

Let us now follow the derivation of 'John begins a book'. Functional composition of **a** with **book** yields a noun phrase that contains the qualia structure of the noun and awaits a property to merge with.

$$\textbf{a} \odot \textbf{book} = \lambda P. \quad \begin{array}{|l|}\hline \text{z} \\ \hline \text{book(z)} \\ Q_F: \begin{array}{|l|}\hline \\ \hline \text{info\_cont(z)} \\ \hline \end{array} \\ \\ Q_C: \begin{array}{|l|}\hline \text{Z} \\ \hline \text{sections(Z)} \\ \text{has(z,Z)} \\ \hline \end{array} \\ \\ Q_A: \textbf{write} \\ Q_T: \textbf{read} \\ \hline \end{array} \quad \oplus\ P(z)$$

Functional composition of **begin** with **a** $\odot$ **book** can only work with a type coercion. The event that **begin** requires cannot be found directly, so no simple link can be made. From the qualia structure of **a** $\odot$ **book** we can for example coerce **read**, and this qualifies as the required event. This coercion step is worked out later.

$$\mathbf{begin} \odot (\mathbf{a} \odot \mathbf{book}) = \lambda\ \text{x. e.} \quad \begin{array}{|l|}\hline \text{y} \\ \hline \text{begin(e)} \\ \text{read(e)} \\ \text{agent(e,x)} \\ \text{theme(e,y)} \\ \text{book(y)} \\ \mathcal{Q} \\ \hline \end{array}$$

The rest of the derivation follows straightforwardly. **begin** $\odot$ **(a** $\odot$ **book)** functionally composed with **john** results in a lambda-DRS.

$$\mathbf{john} \odot (\mathbf{begin} \odot (\mathbf{a} \odot \mathbf{book})) = \lambda\ \text{e.} \quad \begin{array}{|l|}\hline \text{y} \\ \hline \alpha\text{:} \begin{array}{|l|}\hline \text{x} \\ \hline \text{john(x)} \\ \hline \end{array} \\ \text{begin(e)} \\ \text{read(e)} \\ \text{agent(e,x)} \\ \text{theme(e,y)} \\ \text{book(y)} \\ \mathcal{Q} \\ \hline \end{array}$$

Adding tense (**pres**) to the lambda-DRS turns it into a proper DRS – all anaphoric information has been resolved and no antecedent for the presupposed event needed to be accommodated.

$$\mathbf{pres} \odot (\mathbf{john} \odot (\mathbf{begin} \odot (\mathbf{a} \odot \mathbf{book}))) = \quad \begin{array}{|l|}\hline \text{e y} \\ \hline \alpha\text{:} \begin{array}{|l|}\hline \text{x} \\ \hline \text{john(x)} \\ \hline \end{array} \\ \text{now(e)} \\ \text{begin(e)} \\ \text{read(e)} \\ \text{agent(e,x)} \\ \text{theme(e,y)} \\ \text{book(y)} \\ \mathcal{Q} \\ \hline \end{array}$$

Naturally we could just as easily have taken **write** instead of **read**, or for that matter, any of the other events that occur in the qualia structure of **book**. Since **read** and **write** are the only events, the result of coercing **a book** is as follows:

$$\textsc{tc}(\lambda \text{P}.\ \begin{array}{|l|}\hline \text{z} \\ \hline \text{book(z)} \\ \text{Q}_{\text{F}}\text{:} \begin{array}{|l|}\hline \ \\ \hline \text{info\_cnt(z)} \\ \hline \end{array} \\ \\ \text{Q}_{\text{C}}\text{:} \begin{array}{|l|}\hline \text{Z} \\ \hline \text{sections(Z)} \\ \text{has(z,Z)} \\ \hline \end{array} \\ \\ \text{Q}_{\text{A}}\text{: } \textbf{write} \\ \text{Q}_{\text{T}}\text{: } \textbf{read} \\ \hline \end{array} \oplus \text{P(z)}) = \{\ \lambda\text{x.e.} \begin{array}{|l|}\hline \text{z} \\ \hline \text{book(z)} \\ \text{write(e)} \\ \text{agent(e,x)} \\ \text{theme(e,z)} \\ \mathcal{Q} \\ \hline \end{array}\ ,\ \lambda\text{x.e.} \begin{array}{|l|}\hline \text{z} \\ \hline \text{book(z)} \\ \text{read(e)} \\ \text{agent(e,x)} \\ \text{theme(e,z)} \\ \mathcal{Q} \\ \hline \end{array}\ \}$$

5 Conclusions and Further Work

We have shown that Bridging and Coercion can be seen in very much the same light, viz. as using implicit lexical information to accommodate a missing antecedent. In doing so, we have extended Pustejovsky's ideas on Coercion and placed it in a discourse perspective. On the other hand we have extended Van der Sandt's algorithm with Bridging, and thus made it more complete with respect to the linguistic data.

The work presented here is limited to definite descriptions; we have not looked into other presupposition triggers. [Beaver, 1993] mentions the following examples, where inferencing takes place.

(9) Probably, if Jane takes a bath, Bill will be annoyed that there is no more hot water.

(10) If Spaceman Spiff lands on Planet X, he will be bothered by the fact that his weight is higher than it would be on Earth.

In (9) the inference is made that taking a bath uses up a hot water reservoir, in (10) that landing on a strange planet may make changes to your weight. To fit with these examples in the framework we presented in this paper remains for future research.

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