Abstract

This paper discusses a special kind of syntax-semantics mismatch: a noun with a relative clause is interpreted as if it were a complement clause. An analysis in terms of *Lexical Resource Semantics* is developed which provides a uniform account for "normal" relative clauses and for the discussed type of relative clause.

1   Introduction

In this study we will discuss a largely unnoticed type of relative clause which we will call *propositional relative clause* (PRC). PRCs manifest a mismatch between syntactic structure and interpretation: syntactically they are normal relative clauses, but in the semantics an NP which is modified by a PRC is interpreted as a proposition, even though the head noun in itself does not have a propositional interpretation. The clearest cases of PRCs will come from data with idiomatic expressions, in particular with bound words. We will show that the apparent mismatch can be resolved if we adopt a system of combinatorial semantics which exploits techniques of semantic underspecification such as *Underspecified DRT* (UDRT, Frank and Reyle (1995)), *Minimal Recursion Semantics* (MRS, Copestake et al. (2003)), *Constraint Language for Lambda Structures* (CLLS, Egg and Erk (2002)), or *Lexical Resource Semantics* (LRS, Richter and Sailer (2004a)).

A bona fide example of a German PRC is given in (1). The noun *Duzfuß* is a bound word which may only occur in the expression *mit X auf dem Duzfuß stehen* (*be on informal terms with X*). In (1) the noun takes a relative clause which contains the rest of the expression.[1]

(1)   um   den anderen den Duzfuß   ahnen zu lassen, [auf dem   man
      in order to the other   the informal.foot suspect to let   on   which one
      mit   den Spitzenkräften steht].
      with the   top executives   stand
      'in order to make the other one suspect that one is on informal terms with the top executives.'   (from the corpora of the *Institut für Deutsche Sprache*, Mannheim)

Examples such as (1) do not occur frequently in texts and many speakers consider them as "strange" or instances of creative language use. The English translation indicates the only possible interpretation: the NP with the relative clause is interpreted as a complement clause.

[1]The context for (1) is: Eine beliebte Variante ist das Bruderschafts-Dropping, bei dem man geschickt Vornamen wie Thomas, Viktor, Ioan, Otti etc. einflicht, ... ('A popular variant is the "friendship dropping" through which one drops first names such as Thomas, Viktor, ...')

We will assume the following tentative definition of a PRC constellation: A sentence with an NP which is modified by a relative clause such that (i) the sentence is ungrammatical if the relative clause is removed, and (ii) the sentence is synonymous to a sentence in which the NP with the relative clause is replaced with a complement clause with the same lexical material. This is illustrated in (2): since *Duzfuß* is a bound word, it cannot occur freely (a). We can replace the NP with a complement clause to obtain a synonymous sentence (b).

(2) a. *um   den anderen den Duzfuß   ahnen zu lassen
         in order to the other   the informal.foot suspect to let

    b. um   den anderen ahnen zu lassen, dass man mit den
         in order to the other   suspect to let   that one   with the
         Spitzenkräften auf Duzfuß   steht.
         top executives   on informal.foot stands

In this paper we will focus on Lexical Resource Semantics (LRS). We will present a simple semantic analysis of restrictive relative clauses. We will show that this analysis provides the right readings for PRC cases as well, even though in an admittedly surprising way. In the conclusion we will briefly address the conceptual properties of LRS which allow us to account for PRCs.

2   Data

2.1   Propositional Relative Clauses with Bound Words

In this section we will study the properties of PRCs in more detail. We will first have a closer look at the noun *Duzfuß* and then provide examples of PRCs with an other bound word and, in the following subsection, also with free words.

Let us first observe that the expression in (3-a) is decomposable, i.e., it is an *idiomatically combining expression* in the sense of Nunberg et al. (1994). The noun *Duzfuß* can be assigned the meaning indicated in (b).

(3) a. mit jemandem auf (dem) <u>Duzfuß</u>   stehen
         with someone   on the   informal.foot stand
         'be on informal terms with someone'
    b. Duzfuß ↦ informal terms

The noun *Duzfuß* is a bound word. This means that it cannot occur outside the particular expression in (3-a). In (4) we show that *Duzfuß* is even excluded in contexts which are semantically plausible given the meaning assignment in (3-b).

(4) jemandem das Du/   *den <u>Duzfuß</u>   anbieten
      someone   the you(informal)/ the   informal.foot offer
      'to offer someone to switch to informal terms'

Even though the expression in (3-a) is decomposable it is less flexible than

other decomposable idiomatic expressions. In particular the noun *Duzfuß* cannot be modified (a) nor pronominalized (b):

(5) a. Joschka steht mit dem Kanzler   auf (* gutem/ intimem) Duzfuß$_i$.
         Joschka stands with the   chancellor on   good/ intimate informal.foot
     b. *... und auch Angela steht mit Schröder darauf$_i$/ auf ihm$_i$.
         and also Angela stands with Schröder there-on/ on it

Thus sentence (1) exhibits two unusual properties for the noun *Duzfuß*: First it occurs as the complement of a verb which it normally cannot combine with. Second it takes a relative clause, i.e. a syntactic adjunct, even though it cannot be semantically modified. This apparent conflict must be explained on the basis of the interpretation of the noun and the relative clause as a proposition, as illustrated in (2-b) above. It is this unusual interpretation which let us to refer to this kind of relative clauses as *Propositional Relative Clause.*

The noun *Duzfuß* is not the only bound word in German which can occur in PRC constellations. In (6) we provide an analogous example with the bound word *Garaus*. The noun *Garaus* is restricted to the expression in (a). This expression is decomposable, but the bound word cannot be modified. In (b) we give an example of a PRC occurring with this noun. Again we can reformulate the NP with the relative clause in the form of a complement clause, see (c).

(6) a. jdm./ etwas   den Garaus machen 'kill someone/ something'
         to someone/ something the   ??   make
     b. Einzig Vera Kutters ... Negativfoto der   Wiener Secession bleibt   als
         Only   Vera Kutter's ... picture   of the Vienna Secession remains as
         Hinweis auf den Garaus, [den die Nazis der   in ihren Augen
         indication of   the ??   which the Nazis to the in their eyes
         "entarteten Kunst" machten].
         "degenerated art"   made
         'Only Vera Kutter's ... picture of the Vienna Secession remains as an indication of the fact that the Nazis destroyed what to their eyes was "degenerated art"'[2]
     c. ... bleibt als Hinweis darauf,   dass die Nazis der   in ihren Augen
         remains as indication of the fact that the Nazis to the in their eyes
         "entarteten Kunst" den Garaus machen
         "degenerated art"   the ??   made

It should be noticed that PRCs seem to be excluded with non-decomposable expressions. In (7) we show a non-decomposable expression with a bound word (*Maulaffen*). In (b) the expression occurs in a subject clause to the verb *erbosen* (*make angry*). This verb accepts NPs or clauses as subjects. In (c) we try to give a PRC construction which should have the same meaning as (b). However, the sentence is ungrammatical.

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[2]Found by Jan-Philipp Soehn on: http://www.taz.de/pt/2001/11/30/a0123.nf/text.

(7) a. <u>Maulaffen</u>   feilhalten   'stand gaping'
          mouth.monkeys keep for sale

     b. Mich erboste,   dass die Passanten <u>Maulaffen</u>   feilhielten
          me   made angry that the passers-by mouth.monkeys kept for sale
          'It made me angry that the passers-by stood gaping.'

     c. *Mich erbosten   die <u>Maulaffen</u>,   die   die Passanten feilhielten.
          me   made angry the mouth.monkeys which the passers-by kept for sale
          intended meaning as in (b)

2.2   Propositional Relative Clauses with Free Words

PRCs are not restricted to bound words: if a verb semantically requires a propo-
sitional argument but is syntactically compatible with either an S or an NP, an NP
with a PRC can fulfil the requirements. As illustrated in (8) the verb *bedauern*
(*regret*) has these two valence options.

(8) a. Hans bedauerte, dass er beim Spiel das Vermögen verloren hatte.
          Hans regretted   that he had lost the fortune at the game.

     b. Hans bedauerte den Verlust (des   Vermögens)
          Hans regretted   the losing   of the fortune

Even though an NP can occur as the syntactic complement of *bedauern* this NP
must have a propositonal reading. Thus, *bedauern* fulfils the requirements of a
context which allows for PRCs. Indeed we can construct PRC examples:

(9) a. Hans bedauerte das Vermögen, das er beim Spiel verloren hatte.
          Hans regretted   the fortune   that he at the game lost   had
          'Hans regretted that he had lost the fortune at the game.'

     b. *Hans bedauerte das Vermögen.
          Hans regretted   the fortune

As noted above PRCs are only possible with decomposable expressions. The
following set of data shows that this is not only true for expressions whith bound
words, but it carries over to non-decomposable expressions in general. The expres-
sion in (10) is non-decomposable and consists of free words. As expected, the PRC
construction (10-c) is ungrammatical.

(10) a. den Löffel abgeben 'die'
           the spoon away.give

      b. Ich bedauerte, dass er den Löffel abgegeben hatte.
           I   regrettet   that he the spoon away.given had
           'I regretted that he had passed away.'

      c. *Ich bedauerte den Löffel, den er abgegeben hatte.
           I   regretted   the spoon   that he away.given had

2.3 Related Phenomena

2.3.1 Arguments for a "Head Internal" Analysis of Relative Clauses

Similar data have been discussed in the generative literature on relative clauses, first in Vergnaud (1974), later in Carlson (1977), and have recently gained some attention again (for example Valentina (2000)). In (11) we list data from Carlson (1977) which illustrate what he calls an *Amount Relative Clause.*

(11) a. make <u>headway</u>/ progress
      b. *The <u>headway</u> was satisfactory.
      c. The <u>headway</u> [that Mel made] was satisfactory.

In the mentioned approaches these data were used to argue for a syntactic structure in which the head noun originates inside the relative clause and is moved out of it by some operation. Borsley (1997, nd) presents syntactic arguments against such structures for "normal" relative clauses. This would still leave the option that for some relative clauses the head noun originates inside the relative clause, for others it does not. On the other hand we do not find syntactic differences between relative clauses which semantically modify an individual and PRCs.[3]

In addition it is not entirely clear whether the data considered previously are PRCs. In fact there are differences between the German PRC examples and Carlson's Amount Relatives. First, while the noun *headway* is a bound word, just like in our first examples, it can be modified:

(12) They made tremendous <u>headway</u>.

Second, a relative clause to *headway* can occur with verbs which do not require a propositional argument:

(13) I observed the <u>headway</u> [that they made].

An alternative account of the *headway* data would be that *headway*, just like *Verlust* (*loss*) in (8-b), can denote an object of the right semantic type to combine with the verb. Under this perspective there would be nothing particular about the data in (11), except for the fact that *headway* — being a bound word — requires the presence of the support verb *make*.

2.3.2 Reinterpretation Phenomena à la Egg (2002)

We would also like to distinguish between PRCs and other instances of syntax-semantics mismatches. Egg (2002) discusses cases of the following type.

(14) a. Amélie played the sonata for ten days.

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[3]For English Hulsey and Sauerland (2002) argue that whereas "normal" relative clauses can be extraposed this is impossible with relative clauses of the type in (11-c). But notice that no such restriction holds for German: the PRC in (1) is extraposed.

b. beautiful dancer

In (a) an iterative operator must be introduced to make the VP *played the sonata* compatible with the durative adverbial *for ten days*. The NP in (b) has a reading in which the adverbial does not take scope over the entire noun but only over part of it (*person who dances beautifully*). In PRCs on the other hand the head noun is interpreted inside the relative clause and the entire NP has the meaning of a proposition. Thus, in contrast to (a) no additional semantic material is inserted, and in contrast to (b) the adjunct (i.e. the relative clause) does not modify some part of the head noun but integrates the entire semantic contribution of the noun.

With these short remarks we tried to illustrate the differences between PRCs and other kinds of adjuncts which pose problems for a compositional analysis.

3 Lexical Resource Semantics

In this section we will outline the system of *Lexical Resource Semantics* (LRS). After some general remarks in Section 3.1 we will provide those parts of LRS which are needed for our analysis. In the next section we will apply LRS to the relative clause data.

3.1 General Remarks

LRS uses techniques of *underspecified semantics* (Reyle, 1993; Bos, 1996), but the logical form of a sentence is a single, disambiguated expression of the semantic representation language. This special status of LRS between underspecification and more traditional combinatorial systems is discussed in Richter and Sailer (2004a). This paper is also the most extensive introduction to LRS. Previous LRS publications discuss scope ambiguity (Richter and Sailer, 2001; Bouma, 2003), and multiple exponence of semantic operators (Richter and Sailer, 2001, 2004b; Sailer, 2004b). Sailer (2004a) shows how LRS as a system of clausal semantics could interact with lexical semantics.

In LRS the logical form of a sentence is assumed to be an expression of some typed semantic representation language (here: Ty2 (Gallin, 1975)). Since our examples contain definite NPs we include the ι-operator in the semantic representation language. Its use and interpretation is given in (15), taken from Krifka (2004).

(15) For each variable x of type τ and for each ϕ of type t, $\iota x(\phi)$ is an expression whose denotation is an individual a of type τ such that $[\![\lambda x.\phi]\!](a) = 1$ if there is exactly one such individual, otherwise the denotation is undefined.

Consider the following example for illustration. In (16) we indicate the logical form associated with the definite NP *the student.* In Figure 1 we give the subexpressions which make up this logical form. We have chosen for a tree representation to make the structure of the expression clear.

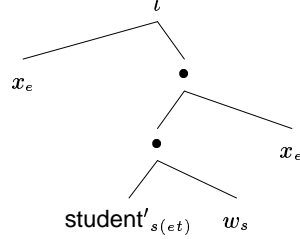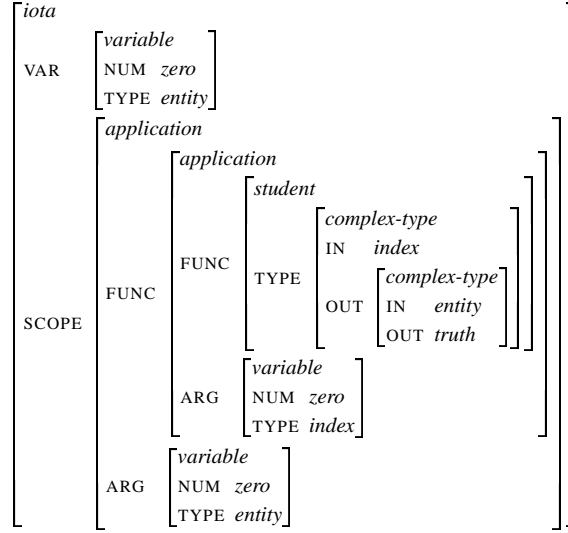Figure 1: Subexpression structure of $\iota x(\mathsf{student}'(w, x))$

$$
\begin{array}{c}
\iota \\
\diagup \quad \diagdown \\
x_e \qquad \bullet \\
\diagup \quad \diagdown \\
\bullet \qquad x_e \\
\diagup \quad \diagdown \\
\mathsf{student}'_{s(et)} \quad w_s
\end{array}
$$

Figure 2: HPSG encoding of $\iota x(\mathsf{student}'(w, x))$

$$
\begin{bmatrix}
\textit{iota} \\
\text{VAR} \quad \begin{bmatrix} \textit{variable} \\ \text{NUM} \;\; \textit{zero} \\ \text{TYPE} \;\; \textit{entity} \end{bmatrix} \\
\text{SCOPE} \quad \begin{bmatrix}
\textit{application} \\
\text{FUNC} \begin{bmatrix}
\textit{application} \\
\text{FUNC} \begin{bmatrix}
\textit{student} \\
\text{TYPE} \begin{bmatrix}
\textit{complex-type} \\
\text{IN} \;\; \textit{index} \\
\text{OUT} \begin{bmatrix} \textit{complex-type} \\ \text{IN} \;\;\; \textit{entity} \\ \text{OUT} \; \textit{truth} \end{bmatrix}
\end{bmatrix}
\end{bmatrix} \\
\text{ARG} \begin{bmatrix} \textit{variable} \\ \text{NUM} \;\; \textit{zero} \\ \text{TYPE} \;\; \textit{index} \end{bmatrix}
\end{bmatrix} \\
\text{ARG} \begin{bmatrix} \textit{variable} \\ \text{NUM} \;\; \textit{zero} \\ \text{TYPE} \;\; \textit{entity} \end{bmatrix}
\end{bmatrix}
\end{bmatrix}
$$

(16)   the student: $\iota x_e(\mathsf{student}'_{s(et)}(w_s, x_e))$

Sailer (2003) explains how expressions of Ty2 can be incorporated into an HPSG grammar, as objects of the sort *meaningful-expression* (*me*). In Figure 2 we give an AVM description of a *me* object which denotes the expression in (16). For our purpose it suffices to see that all syntactic constructs of the semantic representation language are expressed in the HPSG encoding. Furthermore, the structure of the linguistic object described by the AVM in Figure 2 follows that of the expression tree in Figure 1.

In (16) the variable x occurs twice in the logical expression. Similarly the object described by the AVM in Figure 2 has several components which look alike. In HPSG components which look alike can actually be identical. This is achieved by means of *structure sharing*, (also called *token identity*) and constitutes one of the major analytical tools of the framework. The encoding of semantic expression presented in Sailer (2003) is such that all possible identities must actually be present in a linguistic object which represents such an expression. In the case at hand this would mean that the values of the paths VAR and SCOPE ARG are identical.

This discussion of identities seems to focus on a technical property of the HPSG encoding of logical expressions. It will, however, become obvious in Section 4 that this property provides the basis for our analysis of PRCs.

3.2 Brief Outline of LRS

After the general remarks on LRS and on the way expressions of a semantic representation language are integrated into an HPSG grammar, we can outline the combinatorial mechanism used in LRS. The basic intuition underlying LRS is that the logical form of a sentence is the combination of its subexpressions. These subexpressions are contributed entirely by the lexical items which make up the sentence. Consequently we specify in a sign which subexpressions it contributes to the overall logical form. In addition we have to assign some subexpressions a special status, because they play a particular role in the semantic combinatorics.

The semantic information associated with a sign is contained in the value of an attribute L(OGICAL-)F(ORM). The LF value of a sign is of sort *lrs*. This sort is defined in (17).

(17) The sort *lrs*

lrs	EX(TERNAL-)CONT(ENT)	*me*
	IN(TERNAL-)CONT(ENT)	*me*
	PARTS	*list(me)*

The sort *lrs* has three attributes. The PARTS list contains all subexpression which are contributed by the given sign. The other two attributes serve more technical purposes. The INCONT value is the scopally lowest subexpression contributed by the lexical head of a phrase. The EXCONT value is the expression associated with the maximal projection of the head. The EXCONT value of an utterance is the logical form of the utterance. The EXCONT value of an NP is the operator which binds the referential variable of the head noun. In the case of the NP *the student* the EXCONT value is the expression in (16).

General principles govern the relation between the values of the three attributes of an *lrs* object. For our purpose it suffices to state the INCONT PRINCIPLE, the EXCONT PRINCIPLE and parts of the SEMANTICS PRINCIPLE. We will start with the INCONT PRINCIPLE.

(18) The INCONT PRINCIPLE:
   a. In every *lrs*, the INCONT value is a subexpression of the EXCONT value.
   b. In every *lrs*, the INCONT value is an element of the PARTS list.

This principle ensures that the INCONT value of a sign is actually contributed by this sign (clause (a)) and that it will appear in the logical form associated with the maximal projection of this sign (clause (b)).

The EXCONT PRINCIPLE regulates that every expression which is contributed by a lexical item in an utterance will actually appear in the logical form, i.e. in

the EXCONT value, of this utterance. Furthermore no other semantic material is allowed. This is stated in a more technical fashion in (19).

(19)　The EXCONT PRINCIPLE:

> In every utterance, every subexpression of the EXCONT value of the utterance is an element of the utterance's PARTS list, and every element of the utterance's PARTS list is a subexpression of its EXCONT value.

Let us now consider an example, the NP *the red book*. This NP contains the necessary syntactic and semantic ingredients for our analysis of relative clauses: a definite determiner, an intersective modifier and a noun. In (20) we indicate the logical form associated with this NP and the corresponding LF value.[4]

(20)　a.　The red book: $\iota x(\mathsf{book}'(w,x) \wedge \mathsf{red}'(w,x))$

b.
$$\begin{bmatrix} \text{EXCONT} & \iota x(\mathsf{book}'(w,x) \wedge \mathsf{red}'(w,x)) \\ \text{INCONT} & \mathsf{book}'(w,x) \\ \text{PARTS} & \langle x, w, \mathsf{book}', \mathsf{book}'(w,x), \mathsf{red}', \mathsf{red}'(w,x), \\ & (\mathsf{book}'(w,x) \wedge \mathsf{red}'(w,x)), \iota x(\mathsf{book}'(w,x) \wedge \mathsf{red}'(w,x)) \rangle \end{bmatrix}$$

This AVM describes linguistic objects which satisfy the conditions of the INCONT PRINCIPLE and would even satisfy the EXCONT PRINCIPLE if the NP itself were an independent utterance: The INCONT value is an element of the PARTS list and a subexpression of the EXCONT value. Furthermore the EXCONT value consists of all elements of the PARTS list and does not contain other semantic material.

Working in LRS we always have to address the question of which subexpressions of the logical form are contributed by which lexical item. In (21) we underline for each word in the NP the subexpressions it contributes.

(21)　Meaning contributions:

> *the*:　$\underline{\iota x}(\mathsf{book}'(w,x) \wedge \mathsf{red}'(w,x))$　　*red*: $\iota x(\mathsf{book}'(w,x) \underline{\wedge \mathsf{red}'(w,x)})$
>
> *book*: $\iota x(\underline{\mathsf{book}'(w,x)} \wedge \mathsf{red}'(w,x))$

Figure 3 shows the structure of the NP and the LF values for each node. The PARTS lists of the words consist of the expressions which we have underlined in (21). We must, next, state the principle which regulates the relation between the LF value of a phrase and the LF values of its daughters. This is done in the SEMANTICS PRINCIPLE. In (22) we will only give the clauses of the SEMANTICS PRINCIPLE which are relevant for our discussion.[5]

(22)　The SEMANTICS PRINCIPLE:

　　a.　EXCONT and INCONT are shared along a head projection.
　　b.　The PARTS list of the mother contains exactly the elements of the daughters' PARTS lists.

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[4]To keep the AVMs readable we will use logical expressions inside the AVMs and omit some subexpressions ($\mathsf{book}'(w)$ and $\mathsf{red}'(w)$ in (20)).

[5]Clauses for other syntactic structures can be found in Richter and Sailer (2004a).

Figure 3: The structure of the NP in (20)

$$
\begin{array}{c}
\text{NP} \\
\begin{bmatrix}
\textsc{excont}\ \boxed{1}\ \iota x(\mathsf{b}'(w,x) \wedge \mathsf{r}'(w,x)) \\
\textsc{incont}\ \boxed{2}\ \mathsf{b}'(w,x) \\
\textsc{p}\ \langle x, w, \mathsf{b}', \mathsf{b}'(w,x), \mathsf{r}', \mathsf{r}'(w,x), \\
\quad (\mathsf{b}'(w,x) \wedge \mathsf{r}'(w,x)), \iota x(\mathsf{b}'(w,x) \wedge \mathsf{r}'(w,x)) \rangle
\end{bmatrix}
\end{array}
$$

HEAD

Det
$$
\begin{bmatrix}
\textsc{excont}\ \textit{me} \\
\textsc{incont}\ \boxed{1}\ \iota x(\mathsf{b}'(w,x) \wedge \mathsf{r}'(w,x)) \\
\textsc{p}\ \langle x, \iota x([\ldots x \ldots]) \rangle
\end{bmatrix}
$$
the

N′
$$
\begin{bmatrix}
\textsc{excont}\ \boxed{1} \\
\textsc{incont}\ \boxed{2}\ \mathsf{b}'(w,x) \\
\textsc{p}\ \langle x, w, \mathsf{b}', \mathsf{b}'(w,x), \mathsf{r}', \mathsf{r}'(w,x), \\
\quad (\mathsf{b}'(w,x) \wedge \mathsf{r}'(w,x)) \rangle
\end{bmatrix}
$$

HEAD

AP
$$
\begin{bmatrix}
\textsc{excont}\ (\mathsf{b}'(w,x) \wedge \mathsf{r}'(w,x)) \\
\textsc{incont}\ \mathsf{r}'(w,x) \\
\textsc{p}\ \langle x, w, \mathsf{r}', \mathsf{r}'(w,x), ([\ldots x \ldots] \wedge [\mathsf{r}'(x)]) \rangle
\end{bmatrix}
$$
red

N
$$
\begin{bmatrix}
\textsc{excont}\ \boxed{1} \\
\textsc{incont}\ \boxed{2}\ \mathsf{b}'(w,x) \\
\textsc{p}\ \langle x, w, \mathsf{b}', \mathsf{b}'(w,x) \rangle
\end{bmatrix}
$$
book
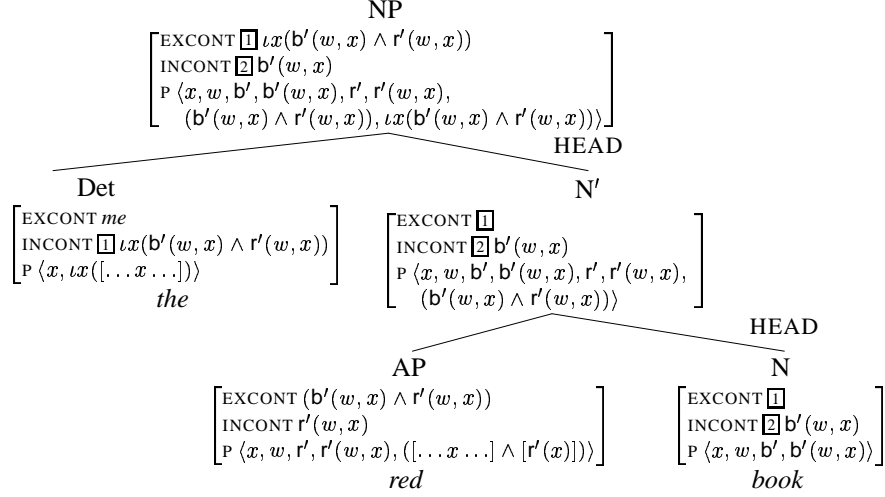
c.　If the nonhead is an intersective modifier which modifies a sign X, then the modifier's EXCONT is of the form $\alpha \wedge \beta$, and X's INCONT is a subexpression of α.

d.　If the nonhead is a determiner, then the nonhead's INCONT and the head's EXCONT are identical, and the head's INCONT is a subexpression of the nonhead's restrictor.

Clause (a) determines that the INCONT value and the EXCONT value percolate along the head projection line. In Figure 3 the effect of this clause is reflected by the use of the tags $\boxed{1}$ and $\boxed{2}$.

Clause (b) guarantees that no semantic information is lost when signs are combined to larger units, nor that any semantic expressions are added. This is why LRS is *lexical*, i.e. all semantic expressions are contributed by lexical items. The syntactic structure can constrain the possible readings but not add new semantic material. This is in contrast to the more constructional approach of MRS.

Clause (c) is needed when a noun combines with an intersective modifier: The EXCONT value of an intersective modifier is a conjunction. The INCONT value of the head daughter must occur as a subexpression of the first conjunct.

Clause (d) describes the effect of a determiner combining with a head noun. Similar to the subexpression condition of clause (c), in clause (d) the INCONT value of the syntactic head is also required to appear as a subexpression of some expression of the nonhead. For a determiner, the noun's INCONT value must be within the restrictor of the determiner's INCONT.[6] The effect of this condition can be seen in Figure 3 where the noun's INCONT value occurs inside the argument of the ι-operator. We have, thus, shown that the combinatorial mechanisms of LRS

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[6]We subsume the only argument of the ι-operator under the notion of "restrictor", even though there is no "nuclear scope" in this case, in contrast to the situation with generalized quantifiers.

license the correct logical form for the given NP, i.e. the expression in (20).[7]

So far we have not mentioned where to locate the attribute LF inside a linguistic sign. Sailer (2004a) argues for a separation of *local* semantics and *semantic structure*, analogous to the distinction between syntactic category and syntactic structure in HPSG. Those aspects which are important for scope and the overall logical form occur inside the LF value. Information which is needed for linking or for semantic selection restrictions appear in the CONTENT value, which is embedded under *local* and, thus, can be accessed by a selector. This local semantic information will also contain the INDEX value. In addition to the ϕ-features which are usually found in the index, we will include an attribute, VAR, whose value is the referential variable associated with the given sign. The AVM in (23) demonstrates this separation for the word *book*.

(23) Outline of the semantic aspects of the word *book*:

$$
\begin{bmatrix}
\text{PHON } \langle book \rangle \\
\text{SYNS LOC} \begin{bmatrix} \text{CONT INDEX} \begin{bmatrix} \text{PERS } \textit{third} \\ \text{NUM } \textit{sing} \\ \text{GEN } \textit{neutr} \\ \text{VAR } x \end{bmatrix} \end{bmatrix} \\
\text{LF} \begin{bmatrix} \text{EXCONT } \textit{me} \\ \text{INCONT } \mathsf{book}'(w, x) \\ \text{PARTS } \langle x, w, \mathsf{book}', \mathsf{book}'(w, x) \rangle \end{bmatrix}
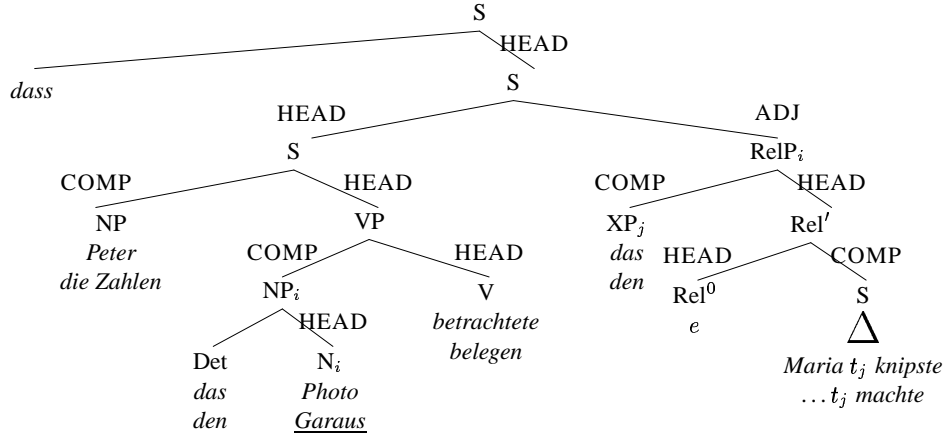\end{bmatrix}
$$

4   Analysis

After this brief introduction of the mechanisms of LRS we can address the analysis of the German relative clause data. In this section we will first present the analysis of a "normal", i.e. semantically modifying, relative clause (Section 4.1), and then turn to the PRC readings in Section 4.2.

PRCs do not differ structurally from other relative clauses. Within HPSG most publications on German relative clauses, such as Kiss (2004) and Holler (2003), assume a variant of the analysis in Pollard and Sag (1994) rather than adopting the constructional approach in Sag (1997). As nothing depends on this, we will follow this line without further argumentation.

In German relative clauses often appear in extraposed position. This is also true for PRCs (see (1)). Kiss (2004) demonstrates that relative clauses are not "moved" into such an extraposed position — in contrast to complement clauses. In order to establish the semantic and agreement relation between an extraposed relative clause and the head noun, Kiss argues in favor of a system of combinatorial semantics which uses techniques of underspecified semantics, MRS in Kiss' case. In Kiss' analysis a relative clause can modify a noun which appears deeper in the

---

[7]There is one other expression which satisfies the indicated principles of LRS: $\iota x(\mathsf{book}'(w, x)) \wedge \mathsf{red}'(w, x)$. In this hypothetical logical form the entire ι-operator appears in the first conjunct. As a consequence the occurrence of the variable x in $\mathsf{red}'(w, x)$ is not bound by the ι-operator. We assume that such a reading will be excluded by general well-formedness conditions.

Figure 4: Syntactic structure of the sentences in (24) and (25)

```
                              S
                              \HEAD
dass                           S
                 HEAD                        ADJ
                  S                          RelP_i
        COMP            HEAD         COMP              \HEAD
        NP              VP           XP_j              Rel'
        Peter       COMP    HEAD     das    HEAD          \COMP
        die Zahlen  NP_i    V        den    Rel^0         S
                  /  \HEAD  betrachtete     e            /\
                Det  N_i    belegen                    Maria t_j knipste
                das  Photo                             ...t_j machte
                den  Garaus
```

syntactic structure. In the present paper we will assume an LRS version of Kiss' theory without providing the details.

We will illustrate our analysis with the following two sentences. Example (24) contains a normal relative clause, and (25) contains a PRC. We will also indicate the logical form. Our semantic representation language allows us to differentiate between semantic objects of different type (entities, eventualities, propositions). We will ignore tense.

(24)   dass Peter das Photo betrachtete, das   Maria knipste.
       that Peter the picture looked.at   which Maria took
       $\lambda w.\exists e(\mathsf{look\text{-}at}'(w,e,p,\iota x(\mathsf{picture}'(w,x) \wedge \exists e'(\mathsf{take}'(w,e',m,x)))))$

(25)   dass die Zahlen den <u>Garaus</u> belegen, den   die Globalisierung dem
       that the numbers the ??   prove   which the globalization   to the
       Kleinbetrieb machte.
       small business made
       $\lambda w.\exists e(\mathsf{prove}'(w,e,\mathsf{Z},\lambda w.\exists e'(\mathsf{make}'(w,e',\mathsf{G},\mathsf{K},\iota x(\mathsf{garaus}'(w,x))))))$

Figure 4 outlines the syntactic structure of the sentences. In the following two subsections we will show how we can derive the correct readings for the sentences in (24) and (25) respectively.

4.1   The "Normal" Case

In this subsection we will combine the syntactic analysis of restrictive relative clauses with an LRS semantics. We will use sentence (24) as our running example. We will first consider the logical form of the deepest S node in Figure 4, then turn to the relative clause and finally address the question of how the relative clause and the rest of the sentence combine semantically.

The semantics of the NP *das Photo* (*the picture*) will be arrived at analogously

Figure 5: Outline of the lexical entry of *betrachten* (*look at*):

$$
\begin{bmatrix}
\text{PHON } \langle \textit{betrachten} \rangle \\
\text{SYNS LOC}
\begin{bmatrix}
\text{CAT ARG-ST } \left\langle \begin{bmatrix} \text{LOC CONT INDEX VAR } y \end{bmatrix}, \begin{bmatrix} \text{LOC CONT INDEX VAR } x \end{bmatrix} \right\rangle \\
\text{CONT } \begin{bmatrix} \text{INDEX VAR } e \end{bmatrix}
\end{bmatrix} \\
\text{LF}
\begin{bmatrix}
\text{EXCONT } \textit{me} \\
\text{INCONT } \mathsf{look\text{-}at}'(w, e, [\ldots y \ldots], [\ldots x \ldots]) \\
\text{PARTS } \langle w, e, y, x, \mathsf{look\text{-}at}', \lambda w.\alpha, \exists e\beta, \mathsf{look\text{-}at}'(w, e, [\ldots y \ldots], [\ldots x \ldots]) \rangle
\end{bmatrix}
\end{bmatrix}
$$
$$\textbf{and } \mathsf{look\text{-}at}' \lhd \beta \qquad \textbf{and } \exists e\beta \lhd \alpha$$

to the example in Figure 3. For the NP *Peter* the value of all semantic attributes (EXCONT, INCONT, the PARTS list, and VAR) only contains the constant p.

The lexical entry of the verb *betrachten* (*look at*) is outlined in Figure 5. A finite verb contributes a lambda abstract over the world index ($\lambda w.\alpha$), and an existentially quantified eventuality variable ($\exists e(\beta)$). We use Greek letters inside AVMs which should be read as meta variables over expressions of the semantic representation language. They indicate that we do not specify the given expression any further in the AVM. Multiple occurrences of the same meta variable refer to the same expression. Below the AVM we note some subexpression conditions. For example $\exists e(\beta)$ must be a subexpression of $\lambda w.\alpha$. This is expressed with a subexpression relation ("$\lhd$"), written as $\exists e(\beta) \lhd \alpha$.

The lexical entry in Figure 5 illustrates nicely how the VAR values of the complements are accessed in order to assign the complements the right slots in the argument positions of the constant $\mathsf{look\text{-}at}'$. This follows the strategy of argument identification of Pollard and Sag (1994). In our case, all we say is that the VAR values of the complements must occur somewhere inside the semantic argument slots, for which we write $[\ldots x \ldots]$ and $[\ldots y \ldots]$.
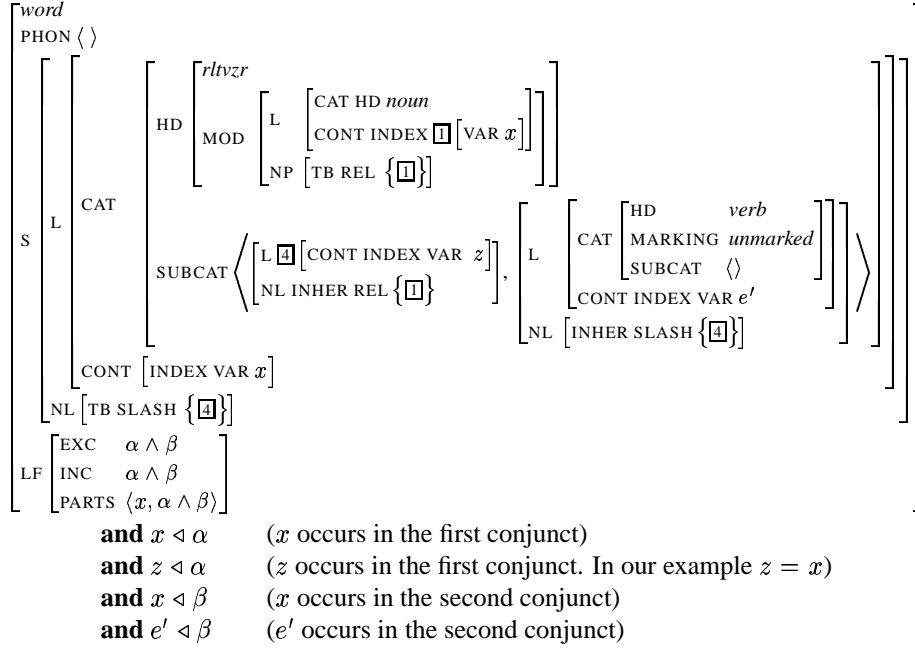
We can now look at the VP and the S node. Since all complements in our examples are definite NPs the SEMANTICS PRINCIPLE does not introduce new subexpression requirements. Nonetheless we can be more specific about the argument slots of the constant $\mathsf{look\text{-}at}'$. The constant p will fill the agent slot. We also know at this stage that the expression $\mathsf{picture}'(w, x)$ occurs in the scope of the ι-operator, but other material might be in there as well. We indicate this "$\ldots$". In (26) we describe the logical form of the discussed S node.

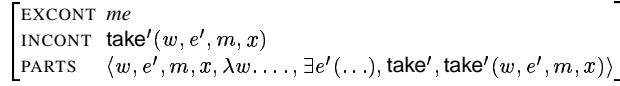(26) The lrs of *Peter das Photo betrachtete*:

$$
\begin{bmatrix}
\text{EXCONT } \textit{me} \\
\text{INCONT } \mathsf{look\text{-}at}'(w, e, p, [\ldots x \ldots]) \\
\text{PARTS } \langle w, e, p, x, \lambda w. \ldots, \exists e(\ldots), \mathsf{look\text{-}at}', \mathsf{look\text{-}at}'(w, e, p, [\ldots x \ldots]), \\
\qquad \mathsf{picture}', \mathsf{picture}'(w, x), \iota x(\ldots \mathsf{picture}'(w, x) \ldots) \rangle
\end{bmatrix}
$$

The logical form of the S node inside the relative clause is built in a parallel fashion. The VAR value of the trace is identical to that of the relative pronoun, which follows from the identity of their LOCAL. The LF value will not add semantic expressions which are not in CONTENT already. We can now describe the LF value of the relative clause internal S node:

Figure 6: The empty relativizer (adapted from (Pollard and Sag, 1994, p. 216))

$$
\begin{bmatrix}
\textit{word} \\
\text{PHON } \langle\,\rangle \\
\text{S} \begin{bmatrix}
\text{L} \begin{bmatrix}
\text{CAT} \begin{bmatrix}
\text{HD} \begin{bmatrix}
\textit{rltvzr} \\
\text{MOD} \begin{bmatrix}
\text{L} \begin{bmatrix}
\text{CAT HD } \textit{noun} \\
\text{CONT INDEX } \boxed{1}\, [\text{VAR } x]
\end{bmatrix} \\
\text{NP } [\text{TB REL } \{\boxed{1}\}]
\end{bmatrix}
\end{bmatrix} \\
\text{SUBCAT} \left\langle \begin{bmatrix}
\text{L } \boxed{4}\, [\text{CONT INDEX VAR } z] \\
\text{NL INHER REL } \{\boxed{1}\}
\end{bmatrix}, \begin{bmatrix}
\text{L} \begin{bmatrix}
\text{CAT} \begin{bmatrix}
\text{HD} & \textit{verb} \\
\text{MARKING} & \textit{unmarked} \\
\text{SUBCAT} & \langle\,\rangle
\end{bmatrix} \\
\text{CONT INDEX VAR } e'
\end{bmatrix} \\
\text{NL } [\text{INHER SLASH } \{\boxed{4}\}]
\end{bmatrix} \right\rangle
\end{bmatrix} \\
\text{CONT } [\text{INDEX VAR } x]
\end{bmatrix} \\
\text{NL } [\text{TB SLASH } \{\boxed{4}\}]
\end{bmatrix} \\
\text{LF} \begin{bmatrix}
\text{EXC} & \alpha \wedge \beta \\
\text{INC} & \alpha \wedge \beta \\
\text{PARTS} & \langle x, \alpha \wedge \beta \rangle
\end{bmatrix}
\end{bmatrix}
$$

and $x \lhd \alpha$ (x occurs in the first conjunct)
and $z \lhd \alpha$ (z occurs in the first conjunct. In our example $z = x$)
and $x \lhd \beta$ (x occurs in the second conjunct)
and $e' \lhd \beta$ (e' occurs in the second conjunct)

(27) The lrs of *Mary t knipste* (*Mary took t*):

$$
\begin{bmatrix}
\text{EXCONT} & \textit{me} \\
\text{INCONT} & \text{take}'(w, e', m, x) \\
\text{PARTS} & \langle w, e', m, x, \lambda w.\dots, \exists e'(\dots), \text{take}', \text{take}'(w, e', m, x) \rangle
\end{bmatrix}
$$

The syntactic structure of a relative clause contains a phonologically empty relativizer according to our assumption. In Figure 6 we will adapt the lexical entry of the empty relativizer from Pollard and Sag (1994) to LRS. We will indicate the effect of the subexpression conditions in brackets for a better readability.

Semantically the empty relativizer only contributes its referential variable (x) and a coordination ($\alpha \wedge \beta$). The subexpression conditions determine that the VAR value of the noun to which the relative clause attaches (x) must occur in both conjuncts. Furthermore the contribution of the S-part of the relative clause must be integrated into the second conjunct. This is expressed by the condition on the event variable e', which is the VAR value of the S-part of the relative clause. Since our examples do not involve pied-piping, we do not have to distinguish between the VAR value of the relative constituent and that of the noun in the MOD (i.e. $x = z$).

When the relativizer combines with its S complement the SEMANTICS PRINCIPLE does not introduce new subexpression conditions. The semantics of the relative pronoun is, again, maximally simple. It only contributes the variable which occurs in its VAR value. Therefore no subexpression conditions are added in the combination of the relative pronoun and the Rel'. The AVM in (28) describes the logical form of the relative clause.

(28)   The lrs of the relative clause:

$$\begin{bmatrix} \text{EXCONT} & [\dots x \dots] \wedge [\exists e'([\dots \text{take}'(w, e', m, x) \dots])] \\ \text{INCONT} & [\dots x \dots] \wedge [\exists e'([\dots \text{take}'(w, e', m, x) \dots])] \\ \text{PARTS} & \langle w, e', m, x, \lambda w \dots, \exists e'(\dots), \text{take}', \text{take}'(w, e', m, x) \rangle \end{bmatrix}$$

In the next step we will combine the RelS with the rest of the sentence. Syntax will ensure that the RelS has the same INDEX VAR value as the noun *picture*. As stated in (28), this value must appear in both conjuncts.

According to (c) of the SEMANTICS PRINCIPLE the INCONT value of the noun must be a subexpression of the first conjunct. Therefore the conjunction must be of the following shape.

(29) $[\dots \text{picture}'(w, x) \dots] \wedge [\exists e'([\dots \text{take}'(w, e', m, x) \dots])]$

The entire conjunction must be a subexpression of $\iota x(\dots)$ in order to bind all occurrences of x. This leads to the following logical form:

(30) $\iota x([\dots \text{picture}'(w, x) \dots] \wedge [\exists e'([\dots \text{take}'(w, e', m, x) \dots])])$

$\iota x(\dots)$ is of type e and, thus, of the appropriate type for the argument position of $\text{look-at}'$. Therefore the expression in (30) can occur there. The relative clause also contributes an abstraction over the world index ($\lambda w \dots$). This abstraction must be outside the scope of the ι-operator. Here it is identical with $\lambda w . \alpha$.

Since no more semantic material will be introduced into the sentence, the EXCONT value of the sentence must contain exactly the elements of its PARTS list. This results in the logical form given in (24), repeated in (31).

(31) $\lambda w . \exists e(\text{look-at}'(w, e, p, \iota x(\text{picture}'(w, x) \wedge \exists e'(\text{take}'(w, e', m, x)))))$

In this subsection we showed that the standard reading of relative clauses can be accounted for by reformulating the semantics of the empty relativizer of Pollard and Sag (1994) in terms of the LRS treatment of intersective modifiers.

4.2   The PRC Case

We will now demonstrate that the PRC reading of (25) can be derived without adding anything new to the present analysis.

The lexical entry of the verb *belegen* (*prove*) is analogous to that of the verb *betrachten* in Figure 5. The only difference concerns the semantic type of the last argument slot. In the case of *betrachten* we assumed that this argument is of type e, for *belegen* it must be a proposition, i.e. of type st.

For simplicity we will abbreviate the semantic contribution of the NPs which are not relevant to the present discussion by upper case letters (Z, G, K). The bound word *Garaus* will be treated analogously to *book* in (23), i.e., it introduces a semantic constant garaus'. We will not provide a treatment of bound words in

this paper.[8] Any account of *Garaus* must ensure that the noun cannot be modified. Therefore the logical form of the NP *den Garaus* is $\iota x(\mathsf{garaus}'(x))$. In contrast to the NP *das Photo* there is no option for inserting further semantic material inside the scope of the ι-operator. We will state the logical form of the lowest S node in (32).

(32) The lrs of *die Zahlen den <u>Garaus</u> belegen*:

$$\begin{bmatrix} \text{EXCONT} & me \\ \text{INCONT} & \mathsf{prove}'(w, e, Z, [\ldots x \ldots]_{st}) \\ \text{PARTS} & \langle w, e, Z, x, \lambda w.\ldots, \exists e(\ldots), \mathsf{prove}', \mathsf{prove}'(w, e, Z, [\ldots x \ldots]), \\ & \mathsf{garaus}', \mathsf{garaus}'(w, x), \iota x(\mathsf{garaus}'(w, x))\rangle \end{bmatrix}$$

The logical form of the S-part of the relative clause is constructed parallel to the previous case. This leads to the following LF value.

(33) The lrs of *die Globalisierung dem Kleinbetrieb t machte*:

$$\begin{bmatrix} \text{EXCONT} & me \\ \text{INCONT} & \mathsf{make}'(w, e', G, K, [\ldots x \ldots]) \\ \text{PARTS} & \langle w, e', G, K, x, \lambda w.\ldots, \exists e'(\ldots), \mathsf{make}', \mathsf{make}'(w, e', G, K, [\ldots x \ldots])\rangle \end{bmatrix}$$

If we combine this clause with the empty relativizer in Figure 6 and with the relative pronoun, we will arrive at the logical form of an intersective modifier.

(34) The lrs of the relative clause:

$$\begin{bmatrix} \text{EXCONT} & [\ldots x \ldots] \wedge [\exists e'([\mathsf{make}'(w, e', G, K, [\ldots x \ldots])])] \\ \text{INCONT} & [\ldots x \ldots] \wedge [\exists e'([\mathsf{make}'(w, e', G, K, [\ldots x \ldots])])] \\ \text{PARTS} & \langle w, e', G, K, , x, \lambda w.\ldots, \exists e'(\ldots), \mathsf{make}', \mathsf{make}'(w, e', G, K, [\ldots x \ldots])\rangle \end{bmatrix}$$

We can now combine the RelS with the rest of the sentence. Again the syntactic analysis will guarantee that the RelS has the same INDEX VAR value as the noun *Garaus*. As we have seen this value appears in both conjuncts of the relative clause semantics. According to (c) of the SEMANTICS PRINCIPLE the INCONT value of the noun must be a subexpression of the first conjunct. Thus, we know that the conjunction must contain the following semantic material.

(35) $[\ldots \mathsf{garaus}'(w, x) \ldots] \wedge [\exists e'([\mathsf{make}'(w, e', G, K, [\ldots x \ldots])])]$

The noun *Garaus* cannot be modified, therefore the coordination cannot be in the scope of ιx, even though this would be the standard logical form for a restrictive relative clause to a definite NP. Since this standard logical form is not available, we must ask whether there is a way to combine the semantic contributions into a well-formed expression at all. In (36) we present a logical form which solves the apparent problem.

(36) $\lambda w.\exists e'((\mathsf{make}'(w, e', G, K, \iota x(\mathsf{garaus}'(w, x)))$
$\wedge \mathsf{make}'(w, e', G, K, \iota x(\mathsf{garaus}'(w, x)))))$

This expression satisfies all subexpression conditions: (i) The semantic contribution of the S-part of the relative clause occurs in the second conjunct. (ii) The variable x occurs in both conjuncts. (iii) The INCONT value of the NP *den Garaus* ($\mathsf{garaus}'(w, x)$) occurs in the first conjunct. The fact that the same material appears in both conjuncts is compatible with these requirements.

We do not even have to assume that the expression $\mathsf{garaus}'(w, x)$ was added twice to the PARTS list. Instead, we can simply use the identical expression, but assume that there are two paths through the overall expression which lead to $\mathsf{garaus}'(w, x)$. But this is an independent property of our HPSG encoding of semantic expressions, as we have seen in Section 3.1. We will outline the HPSG encoding of the conjunction in the following AVM. This AVM shows that the two conjuncts have identical subexpressions.

(37)   HPSG encoding of the conjunction in (36):

$$\begin{bmatrix} \textit{coordination} \\ \text{C1} \;\boxed{1}\; \mathsf{make}'(w, e', G, K, \iota x(\mathsf{garaus}'(w, x))) \\ \text{C2} \;\boxed{1} \end{bmatrix}$$

Let us turn back to the expression in (36). This expression is of type st and can, thus, be used as the semantic argument of $\mathsf{prove}'(w, e, Z, [\ldots x \ldots])$. This leads to the following logical form.

(38) $\lambda w.\exists e(\mathsf{prove}'(w, e, Z, \lambda w.\exists e'((\mathsf{make}'(w, e', G, K, \iota x(\mathsf{garaus}'(w, x)))$
$\wedge \mathsf{make}'(w, e', G, K, \iota x(\mathsf{garaus}'(w, x))))))))$

This logical form is equivalent to the one we gave in (25). It is of course more complicated because it consists of an extra conjunction. But since the two conjuncts are identical, there is no difference in their truth conditions.

In this subsection we demonstrated that the mechanisms of LRS can account for the PRC reading without any stipulation. It should be noticed that we could not have derived a PRC reading for example (24), because the matrix verb does not take a propositional argument.

5   Reflections and Conclusion

Our analysis of PRCs relied on the possibility to use identities of semantic expressions. As illustrated in Section 3.1 this possibility follows from the fact that LRS is fully integrated into HPSG, for which identities are a central analytical device.

Identities have already played an important role in the LRS analysis of concord phenomena. For examples such as (39) Richter and Sailer (2004b) argue that both the preverbal marker *nie* and the n-word *nikomu* contribute a negation to the overall logical form. A language specific principle will specify that Polish does not allow for two negations in one clause — in contrast to French, for example. This principle enforces that the two items contribute the same negation.

(39) Janek nie pomaga nikomu (Polish)
      Janek NM helped   nobody
      'Janek didn't help anybody.'

While identities lead to simpler logical forms in concord constellations, in the current analysis of PRCs, identity is used to "multiply" bits of logical form. This is possible because the conjunction introduced by the relativizer needs two conjuncts of the same semantic type, so we can use the same conjunct twice. Notice that the two conjuncts must be fully identical, i.e., this mechanism does not cover the potential of the so-called *equality-up-to*-constraints in Pinkal (1996) or Egg et al. (2001). It is an empirical question whether we can find more phenomena for which an analysis in terms of "multiplying" may be attractive.

The account presented seems to predict a general ambiguity of relative clauses. Note however that the availability of a PRC reading is correctly restricted to certain matrix predicates. For example we could not have derived a PRC reading for sentence (24). To explain the often dubious grammaticality status of PRC readings we may assume that speakers tend to avoid redundant logical forms, in particular since normally relative clauses can be interpreted without such a redundancy.

In principle the presented analysis can be adapted to other systems of combinatorial semantics which use techniques of underspecification. We saw, however, that it is important to rely on a semantic representation language which allows to distinguish individuals and propositions to prevent overgeneration. Furthermore so far identities of logical expressions have not been exploited in other systems to our knowledge.

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