The Interface between Lexical and Discourse Semantics

The case of the light verb "have"

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Abstract

The macro-target of discourse interpretation for computational purposes is the automatic detection of events in a text and their ordering in a temporal scale. Asher and Lascarides' (2003) ideas on the semantics-pragmatics interface between the lexical and discourse level along with the logic mechanism for inferring rhetorical structure (often nonmonotonically) proposes an interesting way of achieving this macro-target. This talk examines the discourse behaviour of the light verb *have* in English, as in "John *had* his students walk out of class." and proposes an extension of Asher and Lascarides' ideas, primarily with respect to the representation of lexical semantics and the interaction with discourse. Light *have* has previously been analyzed from within lexical semantics as a semantically light element which enters into a complex predication with another predicate (e.g., Ritter and Rosen 1993). This talk argues for a different approach to light *have* by taking discourse structure into account. When one looks beyond the domain of lexical semantics, it becomes evident that light *have* supports the inference of discourse relations and functions as a reliable marker for discourse interpretation.

1 The problematic case of the light verb *have*

1.1 The problem

The analysis of light verbs comprises a challenging enterprise in natural language semantics and syntax. The verb *have* in its light use participates in V+V constructions and shows an ambiguity as to the semantic interpretation of its subject in the complex predicate. This paper provides a possible explanation for the variable semantic behaviour of the subject of *have*.

In (1) for example, John is interpreted as the indirect causer of "wash" but in (2) John is interpreted as the indirect undergoer or experiencer of the "overwatering" event. By indirect causer or receiver I mean that the semantics of the subject can not participate in the denotation of the main event. Additionally, although the terms causer and undergoer are used, the interpretation used in this paper is not the same as the one commonly used in the lexical semantic community. The term of "indirect" causation is used here in a much looser sense than commonly accepted in lexical semantics.

(1) John *had* Jim wash his hands.

(2) John *had* Jim overwater the plants in his office.

Things are more complicated when one encounters sentences like (3) taken from Ritter and Rosen (1993). In (3) one cannot interpret the subject of *have* either as agentive or as experiencer, since both of the readings might be possible in different contexts. Ritter and Rosen (1993) argue for a clear case of ambiguity. One can interpret "John" as

either the causer or the experiencer of the "walking out of class" event. In section (3), I claim that this variable behaviour of the subject of *have* reflects the underspecified semantic role of the light verb *have* at the discourse level.

(3) John *had* half his students walk out of his class.

The paper is organized as follows. The first section presents the problematic behaviour of light *have* as it has been identified by previous syntactic and semantic approaches. The second and third sections discuss ideas of Asher and Lascarides (2003) on the lexical-discourse semantics interface and provide the proposed solution in full length. The fourth section focuses on a specific example; under the current analysis, the reliable computation of the discourse meaning is ensured by focusing primarily on the lexical knowledge associated with light *have*, thereby avoiding a heavy use of domain and world knowledge.

1.2   Prior analyses and assumptions

Light verbs participate in monoclausal complex predications. Within LFG, for example, the predicational power of a complex predicate (main predicate plus a light verb) is equal to an f-structure containing only one predicate and a single subject (Alsina 1996, Butt 1995). This monoclausal f-structure is obtained despite the fact that the argument structure is complex and that the light verb often adds an extra argument (cf. the uses of light *have* in (1)–(3)).

However, the syntactic theories have no real answer to the question of how to isolate the precise semantic contribution of the light verb to a complex predication. The problem of identifying the precise semantic contribution of a light verb is illustrated by light *have* as well. Should one assume two independent lexical entries for light *have*, one which contributes an experiencer to the complex predication ((2)) and one which contributes a causer ((1))? Or should one assume an underspecified entry with an underlying semantics that can result in either an experiencer or a causer reading?

Ritter and Rosen (1993) argue convincingly that one should assume only one underlying lexical entry for *have*. I briefly illustrate their basic analysis and propose to build on it by taking the discourse context more seriously than has been done in previous analyses. It is generally recognized that the choice for the differing interpretation of the subject of *have* depends on the surrounding context. However, even though the importance of the discourse context is recognized (see, for example, Levin and Rappaport 1995), previous analyses of light *have* have focused exclusively on the interface between lexical semantics and syntax.

Ritter and Rosen (1993) propose that the argument contributed by light *have* may not be external to a verb but to an event. According to them, the interpretation of the subject of *have* is not dependent upon the lexical semantic content of the main predicate, but upon the role *have* plays in organizing the event it participates in. Thus, there are two ways of attaching and hence interpreting the external argument of *have* to the event denoted by the main predicate: the causer reading is derived from an anchoring of the external argument before the main event; the experiencer reading is

derived via an anchoring of the external argument after the main event. The basic idea is sketched in (4), which provides an analysis of the ambiguity illustrated iin (3).

(4) have&walk out |—— Cause ——|—— Walk out of class ——|

                        |—— Walk out of class ——|—— Exp. ——|

These analyses are taken from a sentential point of view, but a discoursal perspective onto the same phenomena provides a more useful insight into the reasons of the inherent ambiguous behaviour of the light verb *have*. In order to explore the advantages of integrating lexical and discourse knowledge it is essential to first define the interaction of the two levels of representation. The interface between these two level of description is presented in the next section. It is based on a multi-modular theory of discourse representation and interpretation called Segmented Discourse Representation Theory (SDRT henceforth) introduced by Asher (1993) and further developed by Asher and Lascarides (2003).

2   The interface between the lexicon and the discourse

The representation and inference of textual units has been one of the main focuses of computational semantics since the development of the first dynamic semantic accounts for discourse interpretation by Heim (1982) and Kamp (1983) and later by Kamp and Reyle (1993). It has been applied to discourse processing systems based on the ideas of Hobbs et al. (1993) and other AI techniques. One of the main concerns of those theories is how one can integrate information from totally different direction, which plays a distinct but crucial role to the overall coherent interpretation of the discourse.

After a decade of research in the area, Asher (1993), Asher and Lascarides (2003) tracked the disadvantages of previous approaches and provided a model-theoretic way of interpreting the discourse without excluding crucial information addressed by different knowledge sources, but at the same time maitaining the independence and expressibility required by each of these knowledge sources. The interpretation system is based on a modular inference component called DICE (Discourse in Commonsense Entailment) supported by a modal propositional logic called "glue" or information packaging logic with a nonmonotonic component. This logic contains default inference axioms for several kinds of discourse or rhetorical relations between two segments and is flexible and "flat" (in terms of using underspecified representations) enough to include the necessary knowledge from lexical and compositional semantics as well as domain, world and cognitive modeling knowledge.

SDRT pays particular attention to the contribution of lexical semantic analyses, since in many cases inference and interpretation can be simplified by lexical information. If domain and world knowledge are heavily used, it becomes extremely difficult to end up with a robust analysis, since pragmatic information is not enough to determine the relations between two or more utterances. This important observation and strategy is particularly beneficial in famous cases as in (5) (Asher and Lascarides, 2003).

(5) Max fell. John pushed him.

The right interpretation of this two-sentence discourse is that there is an *Explanation* relation between the two utterances. Classic analyses would suggest that such an inference is based exclusively on indefeasible explicit world knowledge axioms about pushing events that cause falling ones. However, SDRT uses as much linguistic knowledge as possible. In (5), the verb "push" is transitive and entails movement of the object. The kind of movement is further specified by "fall" in the second utterance. By using lexical information for simplifying the discourse inference, one avoids the use of detailed defeasible domain knowledge axioms for every kind of entailment of pushing events.

SDRT's inference engine integrates linguistic knowledge wherever possible and it seems that both discourse and lexical processing methods may benefit from this strategy. Asher and Lascarides (1995) exploit the possibility of building an interface between the lexicon and the discourse and establish a two-way interaction between the two distinct levels of representation. Lexical processing techniques are enhanced by a lexical semantic representation containing rhetorical relations and, therefore, using information from the discourse for word disambiguation tasks, while the inference of discourse relations has been enriched by valuable lexical semantic information.

SDRT uses a set of discourse relations called rhetorical relations as two place predications between two utterance tokens depending on their connection inside the text. These relations attempt to consider pragmatic effects brought about by the discourse and assign them a model-theoretic interpretation. Some of the rhetorical relations used by the theory for various types of texts and purposes among others are *Narration*, *Explanation*, *Result*, *Elaboration*. The inference of these relations is based on a series of default axioms that can be overridden in favour of the discourse coherence. A pragmatic principle and constraint is called Maximal Discourse Coherence (MDC). This ensures that the discourse update procedure takes pragmatic validity under consideration, chooses the pragmatically most preferable interpretations and excludes the implausible ones. Explicit details about this part of the theory are provided in Asher and Lascarides (2003).

Whatever strategy for whatever reasons one picks up to build the compositional semantic representation of a sentence, it has been proved that lexical and discourse inference should be handled in a delicate manner. This paper adopts some of the strategies of Asher and Lascarides (1995) to use the necessary lexical information for discourse inference. These strategies include:

- The use of underspecified lexical representations in SDRS format in cases of ambiguities. This is unlike the usual methods of word sense disambiguation where one deals with disambiguated lexical items and revises choices.

- The avoidance of lexical disambiguation that could lead to discourse incoherence wherever possible.

3   The light verb *have* and its contribution to discourse interpretation

The variable behaviour of the external argument of *have* and the difficulty of pinning down lexical or syntactic factors determining the integration of the external argument,

suggest that its lexical semantic properties should be established with respect to the larger discourse context. Following Tantos (2004), in (6) one can isolate the role of the light verb *have* only if one examines it in a larger context.

(6) (π_1)John was shouting all the time. He (π_2)*had* a student walk out of the class. (π_3) He felt very bad about it.

Extending the picture argued for by Ritter and Rosen (1993) it becomes evident that the role of *have* is not only to organize the event of the main predicate but also to structure the discourse. The second utterance in the discourse describes the indirect causation relation built between the subject of *have* and the event of the main predicate in the causative reading. Therefore, (π_2) builds a causal connection with (π_1) and by using the default inference axiom of *Result* in (7) provided by SDRT, we get the desired intuitive interpretation that the "shouting" resulted in "a student walking out of the class".

(7) $(?(\alpha,\beta,\lambda) \ \& \ Top(\sigma) \ \& \ causeD^1(\sigma,\alpha,\beta) \ \& \ Aspect(\alpha,\beta))>Result(\alpha,\beta,\lambda)$.

(8) $(?(\alpha,\beta,\lambda) \ \& \ Top(\sigma) \ \& \ causeD(\sigma,\beta,\alpha) \ \& \ Aspect(\alpha,\beta))>Explanation(\beta,\alpha,\lambda)$.

The default axiom in (7) says that if two utterances α and β are to be connected with a rhetorical relation, their top node in the discourse is σ and there is evidence from compositional or/and lexical semantics that there is causal relation between them, independently of their aspect, then one should defeasibly infer a *Result* connection between α and β.

On the other hand, the same causal effect is responsible for the experiencer reading of the subject of *have*, which obtains simultaneously with the causative reading in (7). The single event of the complex predicate in (π_2) causes the effect depicted in the next utterance (π_3). The relevant rhetorical relation to be inferred should be *Explanation*, which is the dual relation to *Result* as defined by Asher and Lascarides' (2003) inference axiom (9), where the interpretation of the temporal order of the events is inverted. At this point, it is worth noting the parallelism to Ritter and Rosen's (1993) analysis, who view the two interpretations of the subject of *have* in terms of different attachment possibilities to the event of the main predicate. However, their analysis concentrates on the sentential level and on the interaction between lexical semantics and syntax.

I take this to suggest an underspecified representation at the discourse level for the light verb *have*. This underdetermines which of the two readings is preferable and is expressive enough to cover the causal effect associated with light *have* in both the experiencer and causer readings. In (9) both possibilities of interpretation are illustrated. This reflects the different temporal placements of the event of the main predicate in an unspecified eventuality.

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[1]causeD is a term in SDRT defining the "discourse premissible cause". For more details on the term see Asher and Lascarides (2003).

(9) E_1|——unspec-e_1——||——walk-out-of-class-e_2——||——unspec-s——| E_2

      Event Coreference   Cause   Cause   Event Coreference
      Relation   Relation

(10) E_1|——unspec-e_1——||——walk-out-of-class-e_2——|

      Event Coreference   Cause

(11) |——walk-out-of-class-e_2——||——unspec-s——| E_2

                     Cause   Event Coreference
                                          Relation
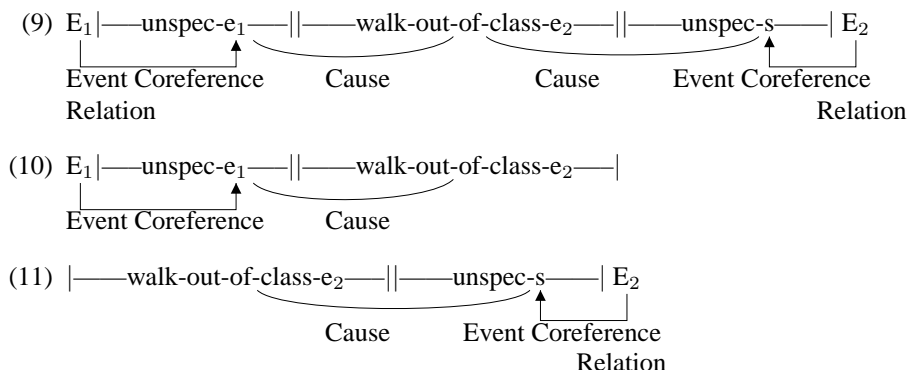
Further details about the different representations illustrated above and the information they contain follow in the next sections. But first an explanation of certain conventions in the above representations is necessary.

In (10) and (11) the causal link associates the single event of the complex predicate (e_2) with an unspecified eventuality (either the eventive e_1 in the causative reading represented in (10) or the stative s in the experiencer one (11)). This in turn is identified with an external eventuality denoted by the context (E_1 and E_2 for (10) and (11) respectively). This tactic is necessary since it is possible that the cause or the effect of this single event is not expressed at all, as in (12).

(12) John *had* me push him strongly in the back. Nothing happened. The pen was still in his neck.

In (12) the indirect causation is not explicitly mentioned in the text. However, human interpreters can infer that "John" did something to "me" so that i push him in the back. Although what "John" did is not explicitly mentioned, the reader does not face any problem in the interpretation. If the text clarifies it later it is perfectly acceptable; if it is not clarified, the reader can still move on by keeping in mind that "John" did something whatever that might be. Furthermore, the implicit inference about the unspecified eventuality invoked by *have* has to do with the fact brought by the third sentence that the pen was in "John's" neck and this explains why "John" *had* "me" push him. Therefore, we need to allow for the presence of an unspecified eventuality that can or can not be identified with another eventuality in the context.

As mentioned previously, the ambiguous nature of the light verb *have* can be captured by an underspecified representation. Any of the currently available formalisms of underspecification could be used, since the main idea is that the disambiguation process follows the building of a shallow representation by satisfying constraints on tree structure logic formulas. The lexical representation in Figure 1, built in terms of an SDRS, leaves uninstantiated the argument slots in the causeD predication.

The '?' denotes underspecified information (see Asher and Pustejovsky 2000, Asher and Lascarides 2003) that can be specified as part of the discourse analysis, which in turn relies on linguistic clues within the *have*-clause and the surrounding discourse as much as possible (see discussion below). As can be seen in Figure 1,

$$\begin{array}{|c|c|}\hline \pi_1 & \begin{array}{|c|}\hline e_1 \\ \hline \text{main-predicate}(e_1) \\ \hline \end{array} \\ \pi_2 & \begin{array}{|c|}\hline e_?,x \\ \hline ?(e_?,x) \\ \hline \end{array} \\ \text{causeD}(\pi_?,\pi_?) \\ e\pi_? < e\pi_? \\ \hline \end{array}$$
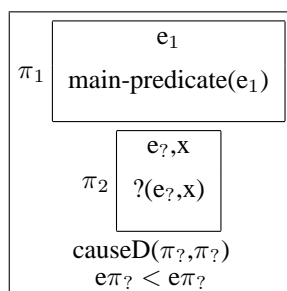
Figure 1: The lexical representation of *have*

the lexical entry for *have* specifies that there must be another eventuality in the clause (labeled π_1). This stands for the verb combining with have, called "main-predicate" in Figure 1 for ease of exposition. We also postulate that part of the semantic contribution of light have is an unspecified eventuality ($e_?$). Although this unspecified eventuality is introduced by *have*, it does not denote *have* itself. Rather, it is a pointer to the unspecified eventuality just mentioned above. Also, the question mark outside ($e_?,x$) is supposed to be predicated of the eventuality and "x" and serves as a place holder for an unknown predicate that will resolve the anaphora in the discourse level.

3.1 Inference and interpretation with light *have*

Asher and Lascarides (1995) use HPSG (Head Phrase Structure Grammar) to establish the connection between a lexical syntactic description and a DRS-like lexical representation. They used the rich type inventory provided by HPSG grammars and the useful tools of reentrancy and unification to drive the semantic composition based on the syntactic description of the properties of the lexical item. These ideas may be applied to any other unification-like formalism, although the different architecture choices should lead to different kinds of analyses.

This paper assumes an LFG (Lexical Functional Grammar) based syntactic representation. LFG is a grammatical theory that proposes a modular projection architecture for the distinct levels of analysis, where each level of description can use individual methods of representation according to its needs and purposes. In that respect LFG resembles SDRT, since both do not provide a derivative model of description but build interfaces —in terms of SDRT— or correspondence functions — in terms of LFG. The syntactic analysis of the *have* sentence from (6), repeated below in (13), is expressed by the f-structure in (14).

(13) (π_1)John was shouting all the time. He (π_2) ($\pi_{2'}$)*had* a student walk out of the class. (π_3) He felt very bad about it.

(14)

$$
\begin{bmatrix}
\text{PRED} & \text{'have}<(\uparrow \text{SUBJ}) \text{ 'walk-out}<(\uparrow \text{OBJ}_\theta), (\uparrow \text{OBL})>'>' \\
\text{TNS-ASP} & \begin{bmatrix} \text{TENSE} & \text{PAST} \end{bmatrix} \\
\text{SUBJ} & \begin{bmatrix} \text{PRED} & \text{'PRO'} \\ \ldots \end{bmatrix} \\
\text{OBJ}_\theta & \begin{bmatrix} \text{PRED} & \text{'student'} \\ \ldots \end{bmatrix} \\
\text{OBL} & \begin{bmatrix} \text{PRED} & \text{'class'} \\ \ldots \end{bmatrix} \\
\text{VTYPE} & \text{LIGHT-HAVE}
\end{bmatrix}
$$

Following the analysis of complex predicates proposed by Butt et al. (2003a) and Butt et al. (2003b), the main PRED of the clause is a complex predicate and it has been put together in the syntax via the restriction operator. The complex argument structure is represented as part of the complex PRED and shows that the light verb *have* is responsible for contributing an extra argument to the predication.[2] This extra argument functions as the subject of the complex predicate. The agent of the main event "walk" is realized as the object of the complex predicate and the feature VTYPE is the one that triggers the underspecified lexical representation assumed in Figure 1.

LFG assumes that the f-structure provides those bits of syntactic information that are relevant for further semantic analysis (or machine translation). This assumption is also made in this paper, and as is also standardly assumed, the mapping to semantics is done via the correspondence function σ, which maps f-structures to semantic formulas of any kind of compositional semantic framework. In particular, this paper assumes the ideas presented in Dalrymple (1999) on building compositional semantics based on a resource sensitive procedure driven by linear logic deduction.

The inference of the right relations is based on the main ideas of DICE and is enriched by the contribution of syntactic information at f-structure. The transformation of f-structures into wffs of the glue logic used by DICE is done by using the Attribute Value Logic (AVL) of Johnson (1988). The "translation" from feature descriptions into propositional modal formulas is done in two steps. First, comes the satisfaction of the attribute-value descriptions in the sentential level in terms of Johnson's (1988) AVL. Johnson (1988)[3] has studied the use of a first order quantifier free logic to describe the constraints imposed by lexical items and syntactic rules in order to get the final attribute-value structure at the top syntactic (S or IP) level. In terms of his system, attribute-value structures play only one role: they are defined in order to give a semantics for the language that describes them. Furthermore, following his steps and the original distinction proposed by Kaplan and Bresnan (1982), this paper adopts the distinction between description of a feature structure and the structure itself. In that

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[2]For reasons of space, this f-structure has been abbreviated to show "preds-only". For a fuller discussion of f-structures and the grammar development platform XLE, see Butt et al. (1999).

[3]Blackburn (1991) has also worked on defining the semantics of feature structures in a modal logic framework, but his focus is on transferring typed feature structures something which this work does not adopt.

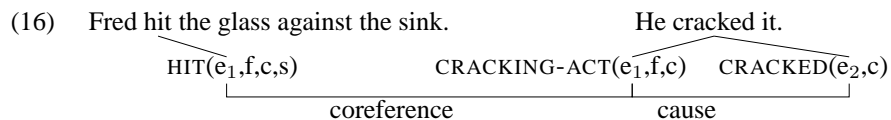way, one can operate on descriptions of attribute-value structures in a flexible way.[4]

3.2 The causative reading

The subject of light *have* is disambiguated through the context. Although in (13) there is no surface clue that calls for the existence of causation, (π_2) builds a causal connection with (π_1) by considering the lexical information provided by *have*. The immediate inference axiom for disambiguation towards a general causative reading, triggered by the verb *have*, is illustrated in the monotonic indefeasible implication of (15).

(15) $\mathrm{have}(x, e\beta) \rightarrow \mathrm{causeD}(?\alpha, \beta)$

This axiom contains mixed information from the lexical and discourse level. It states that if we encounter *have* with its subject argument "x" and an utterance token β that includes the event "e", then one can monotonically infer that there is a causal connection "causeD" and as a second one an event '$e\beta$', then a causal connection can be made between a proposition token '$?\alpha$' that includes the unspecified causing event and a second one 'β' that belongs to the syntactic configuration of *have*, namely the proposition token that includes the main predicate.

In order to get the right interpretation in (13) I propose to use and to apply the above inference axiom. In this direction, one needs to proceed in building the event coreference relation between the unspecified eventuality implied by "have' and another event from the context with techniques introduced by Danlos (2000). Briefly, Danlos' (2000, 2003) analysis departs from the commonly accepted fact that causative verbs should be analysed in terms of a complex predication involving a causing subevent (e_1) which brings about a new state (e_2) (e.g., Hale and Keyser 1993, Higginbotham 2000). Under Danlos' analysis, the causing subevent needs explication that comes from the discourse, and the causative verb creates an anchor between its resulting state (e_2) and the explicative coreferent event, which is obtained by a verb from the previous or following utterance. So, in (16), taken from Danlos (2001), there is a coreference relation between the hitting event of the first clause and the cracking causing subevent of the complex event denoted by the verb 'crack' in the second clause.

(16)   Fred hit the glass against the sink.   He cracked it.

   $\mathrm{HIT}(e_1, f, c, s)$ $\mathrm{CRACKING\text{-}ACT}(e_1, f, c)$ $\mathrm{CRACKED}(e_2, c)$

                  coreference   cause

The coreference relation between the hitting and the cracking event can be computed by implications describing lexico-semantic relations, like hyponymy between the events described by the verbs "hit" and "crack". Taking the parallel case of *have*,

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[4]Negation and disjunctions on feature descriptions are allowed. In contrast, unification theories that suggest that attribute-value structures are directly associated with lexical items and syntactic rules are not able to handle disjunction or negation, since it is not conceivable what the disjunction of an attribute-value structure would mean.

one can see that it signals that two utterances are to be connected via indirect causation. The main difference is that the relation between the unspecified eventuality implied by *have* and the "external" one is not computed in terms of lexico-semantic connections, since *have* does not give clues as to the nature of the unspecified causing eventuality. Exactly this fact makes the main difference between purely causative verbs and the light verb *have*, namely that *have* provides weaker indications for the building of the possible event coreference relations. The second difference is important for theoretical considerations, since causative verbs involve two subevents very closely related by the causation relation, while under my assumptions *have* relates two events denoted by different verbs only indirectly. Nevertheless, in this paper we can see that it is feasible to build such connections based on specific constraints that *have* imposes on the discourse as shown below. Tantos (2004) has shown that in real texts that include the light verb *have*, certain constraints must be satisfied by the discourse until a resolution is realized in favour of a causative or experiencer interpretation. The constraints that should be satisfied in favour of the causative reading and instantiate the inference axiom in (15) are given below.

- The subject of *have* is anaphorically bound with an entity introduced in one of the previous or following discourse accessible utterances [5] which is always assigned the role of agent by its verb.

- The eventuality type denoted by the verb whose subject is bound with the subject of *have* is always "event".

- This "external" event should be instantiated before the event denoted by the main predicate.
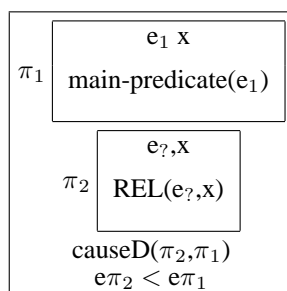
These theoretical observations need to be encoded in axioms of mixed knowledge from syntax, argument structure and discourse semantic representations. The point of complexity in such kind of constraints is that they not only require that two entities corefer, but that their syntactic function and semantic role in the distinct sentences to which they belong should be identical as well. So, one would have to find a way to resolve the anaphora in a restricted way; namely one has to search between the accessible referents whose syntactic function and semantic role is the same with the constraints brought by *have*.

Formally, the corresponding constraints are represented by the following formulas, which include mixed knowledge from different knowledge sources:

- $(\delta_c((\alpha, \text{SUBJ}_{have}) = \text{PRED}^{[6]})$ & $\text{PRED} \rightsquigarrow x)$ & $\exists \text{PRED}_i ((\delta_a(\alpha, \text{SUBJ}_{REL}) = \text{PRED}_i)$ & $(\delta_a(\alpha, \text{AGENT}_{REL}) = \text{PRED}_i)$ & $\text{PRED}_i \rightsquigarrow y))$ & $x=y$

- Eventuality type of $e\pi_? = \text{event}$

- $e\pi_? < e\pi_2$

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[5]Here it is meant between the accessible utterances in the discourse tree.

[6]This is the instantiation of the subject of *have* whether it is a pronoun or a proper name; the same applies to the other PRED.

$$\begin{array}{|c|}\hline \pi_1 \begin{array}{|c|}\hline e_1 \ x \\ \text{main-predicate}(e_1) \\ \hline \end{array} \\ \pi_2 \begin{array}{|c|}\hline e_?,x \\ \text{REL}(e_?,x) \\ \hline \end{array} \\ \text{causeD}(\pi_2,\pi_1) \\ e\pi_2 < e\pi_1 \\ \hline \end{array}$$

Figure 2: The representation of *have* in the causative reading

The notation of the first constraint needs some clarification, since the current work primarily follows the AVL adopted by Johnson (1988) but has been slightly revised because of current considerations about the availability of lexical information in the discourse level. Briefly, the δ predications in the first constraint denote a function from the domain of attribute value elements to attribute value elements whose first argument inside the brackets is the element which contains the attribute of the second position; e.g. in the first δ function, the α element that contains the SUBJ attribute as one of its elements, is mapped to the attribute PRED. Additionally, functional descriptions in the form of AVL formulas are assigned the subscripts "c" to denote information of the current utterance and "a" to denote information of the discourse accessible utterances. By marking the pieces of information in this way, one can exploit the constraints about availability in the discourse structure and at the same time use the information coming from syntax in terms of functional structure descriptions. Furthermore, "x" and "y" stand for discourse referents and the arrow from attributes to referents represents the mapping from syntactic to semantic representation. Finally, the last conjunct adds the crucial coreference of "x" with "y". In other words, the first constraint says that the subject of *have* is assigned a PRED value [7] and that there exists some PRED_i[8] that belongs to the syntactic representation of the discourse available segments that is assigned the grammatical function SUBJ of an unknown predicate REL, its semantic role is AGENT and is mapped to a referent "y". Also, the two referents should be anaphorically bound in the semantic representation of the discourse.

The second and third constraints encode the relevant conditions about the type of the eventuality that the "external" predicate should denote and about the temporal position of the events denoted by the "external" predicate and the main predicate of the complex predicate respectively.

The second step is trivial and partially follows the algorithm of Asher and Lascarides (2003) for building formulas in their "glue" logic, the main constituent of DICE for updating the discourse. Nevertheless, it is not the subject of this paper to in-

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[7]In fact, PRED is an attribute, but it is used here as an variable that is instantiated.

[8]The existential quantification applies over the domain of a restricted set of PREDs that includes the discourse available functional descriptions.

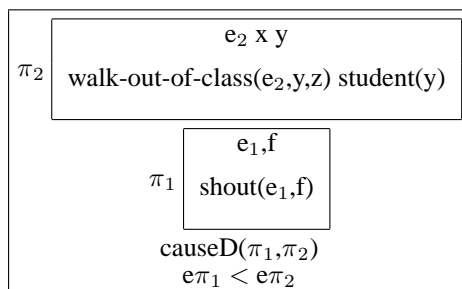$$\boxed{\begin{array}{l} \pi_2 \boxed{\begin{array}{c} e_2 \ x \ y \\ \hline \text{walk-out-of-class}(e_2,y,z) \ \text{student}(y) \end{array}} \\[2em] \qquad \pi_1 \boxed{\begin{array}{c} e_1,f \\ \hline \text{shout}(e_1,f) \end{array}} \\[2em] \qquad\qquad \text{causeD}(\pi_1,\pi_2) \\ \qquad\qquad e\pi_1 < e\pi_2 \end{array}}$$

Figure 3: The instantiated lexical-discourse representation of the example

vestigate the properties of such transfer between the logic assumed here for the feature descriptions and the "glue" logic[9]. The above constraints imposed by a lexical item override the limits of the sentence and/or proposition and show that there is a clear interaction between the lexical and discourse level. The event coreference relation between the unspecified event implied by *have* and an external event from the context resolves the underspecification inherent at the lexical representation of *have* and the desired instantiation of the underspecified representation is taking place as illustrated in Figure 2.

The instantiated representation in Figure 3 gives us the desired results. The arguments in the causeD predication have been resolved, the temporal order of the events has been determined and the REL predicate (which designates the unknown external verb in this case) has been instantiated by the relevant predicate. In this way, specific linguistic observations can be exploited by a discourse analysis and lexical items are able to specify a constrained connection with items from the surrounding utterances.

Now let us try to compute the meaning of the small discourse in (13). Inserting lexical knowledge in the discourse level includes the introduction of a new utterance token ($\pi_{2'}$) following the above lexical representation. The resolution of the under-specified entry in favour of one or the other reading depends on which utterance is related with the utterances represented by *have*. The sentence that contains *have* interprets its subject as causative with respect to (π_1) and experiencer with respect to (π_3).

The position of the arguments in the causeD predication is fulfilled if the constraints of one of the two readings are satisfied. In the case of relating (π_2) with (π_1) in (14), the three constraints described above for the interpretation of the causative reading are satisfied. The set of accessible utterances includes only (π_1). The referent in (π_1), mapped to the SUBJ attribute, is identified with the referent mapped to the SUBJ of *have* and is assigned the semantic role of agent. Furthermore, the eventuality type denoted by the verb "shout" is an "event" satisfying the second constraint. Therefore, establishing the temporal relation $<$ that creates a partial order between events

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[9] An extended discussion about the relevant algorithm can be found in Asher and Lascarides (2003).

in the discourse, "shouting" < "walking-out-of-the-class" means that the "shouting" event occurred before the "walking-out-of-the-class" event.

The instantiated lexical-discourse interpretation is as in Figure 3[10] and the inference of the right rhetorical connections between the utterances is now feasible. The antecedent of the default axiom for *Result* is satisfied and through the application of a weaker version of modus ponens introduced by DICE, called Defeasible Modus Ponens, one arrives at the intuitively correct interpretation. The "shouting" caused the "walking-out-of-the-class" event.

The interaction between lexical and discourse semantics proposed here, is defined in terms of underspecified lexical entries which can be resolved with the help of discourse information. Therefore, the inference and interpretation of the discourse will resolve the lexical underspecification and provide the necessary interpretation axioms for the lexical item of *have* in the discourse. Tantos (2004) describes the semantic contribution of "have" with the interpretation axiom in (17).

(17) $\text{have}_{\text{causative}}(x, e\beta) \rightarrow \text{cause}(e\alpha, e\beta) \,\&\, \text{Agent}(e\alpha, x) \,\&\, e\alpha < e\beta$

This axiom states that if the discourse implies the causative interpretation, then in the model there has to be a causation relation between the two events $e\alpha$ and $e\beta$ belonging to the distinct utterance tokens α and β, the subject of *have* should be assigned the role AGENT and the event $e\alpha$ occured before the event $e\beta$.

3.3 The experiencer reading

The inference over and interpretation of the subject of *have* in the experiencer reading are driven by the same strategy and principles. There is also a causal relation between an "external" event and the event denoted by the main verb of the complex predicate. The main difference is that the "external" event is affected by the event of the main predicate of the complex predicate and not the other way around as in the causative interpretation. Therefore, the inference axioms are different. In (13) the "walking out of the class" event is interpreted as affecting the subject of *have* if the sentence is related with the coming one. Thus, the discourse context provides information about the kind of affectedness involved. The underspecified lexical representation of *have* is instantiated so that the arguments in the causeD predication take the right position and the events are placed in the right temporal order.

The inference axiom for the experiencer is similar to the one for the causative reading, but with the inverse order of the arguments, as shown in (18).

(18) $\text{have}(x, e\beta) \rightarrow \text{causeD}(\beta, ?\alpha)$

Again, one needs to build the coreference relation between the unspecified eventuality included in an accessible utterance token $?\alpha$ and the event of the complement in order to apply the above inference axiom. The building of such a coreference relation requires that new constraints need to be satisfied.

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[10]I ignore the representation of plurals and the contribution of the prepositions here for reasons of simplicity of illustration

- The subject of *have* is anaphorically bound to an entity introduced in one of the previous or following discourse accessible utterances [11] and is always assigned the role of experiencer by its verb.

- The eventuality type denoted by the verb whose subject is bound to the subject of *have* is always "state", since only stative verbs have "experiencer" subjects.

- This "external" event should be instantiated after the event of the main predicate of the complex predicate, since it is affected by it.

Following the mapping of syntactic information by AVL, the relevant constraints for the satisfaction of the inference axiom (18) are:

- $(\delta_c((\alpha, \text{SUBJ}_{have})=\text{PRED})$ & $\text{PRED} \rightsquigarrow x)$ & $\exists \text{ PRED}_i ((\delta_a(\alpha, \text{SUBJ}_{REL}) = \text{PRED}_i)$ & $(\delta_a(\alpha, \text{EXPERIENCER}_{REL}) = \text{PRED}_i)$ & $\text{PRED}_i \rightsquigarrow y))$ & $x=y$

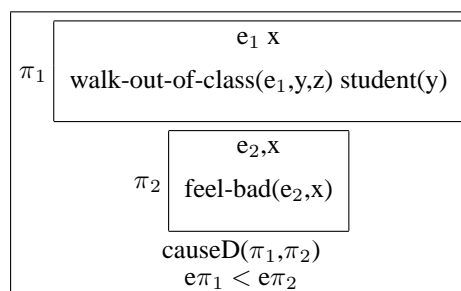- Eventuality type of $e\pi_? = $ state

- $e\pi_2 < e\pi_?$

In (13), the interpretation of the third segment in relation to the second one is that its event is causally affected by the main predicate of the second sentence and this is driven by the resolution of the lexical underspecification expressed by *have* in the second sentence. The instantiation of the underspecified lexical entry in the case of the experiencer reading in (13) is as in Figure (4). As in the resolution of the causative lexical representation, one checks whether the above constraints are satisfied. The "external" predicate represented by the predicate "feel" maps its subject to the same referent introduced by *have*, namely "x". The eventuality of π_2 that is denoted by the main predicate "walk out of the class" of the complex predicate affects the eventuality denoted by the "external" predicate "feel" in π_3 and therefore it occurs before it. Additionally, the predicate "feel" assigns the experiencer role to its subject, satisfying all the constraints for the resolution of the lexical entry. The event coreference relation is thus realized successfully and the discourse representation of π_2 and π_3.

4   Conclusion and further thoughts

The analyses for both of the readings of the light verb *have* provide an example of how one can exploit the linguistic information supplied by the context and lexical semantics in order to succeed in the semantic analyses of texts.

The light verb *have* provides an interesting case study for looking at the inter-action between lexical semantics and disourse. The current approach brings a new insight into the disambiguation process, since it attempts to integrate a formal theory of discourse interpretation. Also, this paper represents a first step towards building a formal relation between SDRT and LFG, using the AVL proposed by Johnson (1988).

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[11]This means that between the available discourse utterances following the principle of accessibility imposed by the discourse structure

$$\pi_1 \boxed{\begin{array}{c} \mathrm{e}_1 \; \mathrm{x} \\ \hline \text{walk-out-of-class}(e_1,y,z) \; \text{student}(y) \end{array}}$$

$$\pi_2 \boxed{\begin{array}{c} \mathrm{e}_2,\mathrm{x} \\ \hline \text{feel-bad}(e_2,x) \end{array}}$$

$$\text{causeD}(\pi_1,\pi_2)$$
$$\mathrm{e}\pi_1 < \mathrm{e}\pi_2$$

Figure 4: The representation of *have* in the experiencer reading

However, it is by no means implied that these and only these constraints for the resolution of the lexical underspecification apply in order to disambiguate all the cases of the light verb *have*. Domain and world knowledge must be included as a necessary last resort for the disambiguation of the light verb *have* when the above linguistic constraints cannot be met.

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