Abstract

Most researchers now agree that subcategorization correlates significantly with semantics. But this semantic component of linking has proved elusive. Most, if not all, theories of linking have, in pratice, resorted to constructs that are syntactic diacritics. We show in this paper that the implicit syntactic diacritics that plague the basic linking constraints posited in at least some of these theories can be eliminated, provided that (i) the metalanguage in which linguistic constraints are written allows for true implicational statements; (ii) one is willing to slightly increase the number of linking constraints. We focus in particular on the linking theory presented in Davis and Koenig 2000, Davis 2001, and Koenig and Davis 2000, but we maintain that our arguments apply, mutatis mutandis, to many other linking theories. We note some of the consequences of this view of linking, including: linking constraints are stated in terms of semantically natural classes of situations, a single entailment of a verb's argument is sufficient to determine its linking, and interaction among linking constraints restricts the range of possible lexical items.

Most researchers now agree that subcategorization correlates significantly with semantics (see, among others, Foley and Van Valin (1984), Pinker (1989), Jackendoff (1990), Levin (1993), Goldberg (1995), Wechsler (1995b), Davis and Koenig (2000b)). To put it in motto form, knowing the meaning of a verb is to a large extent knowing its context of occurrence. But this semantic component of linking has proved elusive. Most, if not all, theories of linking have, in pratice, resorted to constructs that are syntactic diacritics. We show in this paper that the implicit syntactic diacritics that plague the basic linking constraints posited in at least some of these various theories can be eliminated, provided that (i) the metalanguage in which linguistic constraints are written allows for true implicational statements; (ii) one is willing to slightly increase the number of linking constraints. Because of space considerations, we focus in particular on the linking theory presented in Davis and Koenig (2000b), Davis (2001), and Koenig and Davis (2001). But we believe our arguments apply, *mutatis mutandis*, to many other linking theories.

1 Syntactic diacritics in semantically-based linking theories

We first briefly present the approach to linking in HPSG described in Davis and Koenig (2000) and Davis (2001). This linking theory is based on three crucial ideas: (1) A multiple inheritance hierarchy of semantic relations; (2) a multiple inheritance hierarchy of predicator types defined by how they link attribute values within their CONTENT to members of the ARG-ST list (more precisely, to the situational nucleus of their CONTENT); (3) a metatheoretical constraint on the relationship between the hierarchy of semantic relations and the hierarchy of predicator types.

[†]We thank Detmar Meurers for discussing some of the issues raised in this paper. All remaining errors are solely ours.

Consider how this theory accounts for the linking of arguments displayed in the following simple transitive sentence.

(1) Sandy moved the ball.

The fact that, for all English transitive verbs that denote causes changing the states of entities, the cause is realized as the subject of its active form, and the entity changing state is realized as the direct object, is modeled through the interaction of three constraints. First, the CONTENT of *move* includes a semantic relation which is a subtype of both *act-rel* and *und-rel*. This is illustrated in figure 1 where lines between nodes labelling semantic relations indicate a subtype-supertype relation. Such a semantic hierarchy, which encodes the (linguistically relevant) relations between categories of situations, helps restrict the grammatical constraints on the realization of semantic arguments to the proper semantically-defined class of verbs.

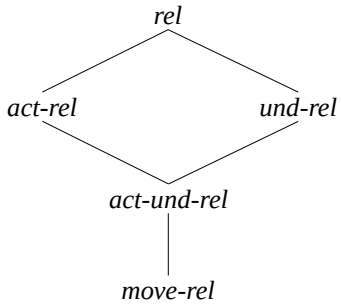


Figure 1: A portion of the semantic relations hierarchy

Second, *move* is a subtype of the type *act-pred* and *und-pred* which require the values of their ACTOR and UNDERGOER attributes to be identical to the values of the CONTENT attribute of the first and second members of the ARG-ST of the verb, respectively, as shown in Figure 2.

$$\begin{bmatrix} \textit{act-pred} \\ \text{CONTENT} \begin{bmatrix} \textit{act-rel} \\ \text{ACTOR } \boxed{1} \end{bmatrix} \\ \text{ARG-ST} \quad \langle \text{NP:}\boxed{1}, \ldots \rangle \end{bmatrix}$$

(a) The type *act-pred*

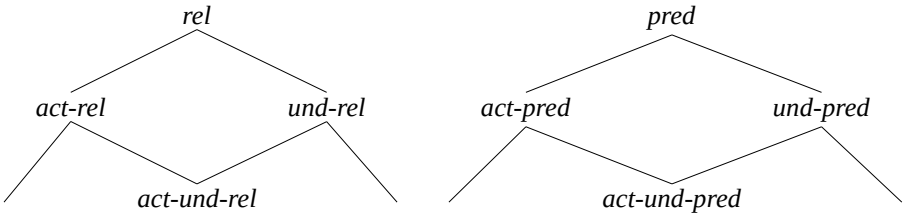
$$\begin{bmatrix} \textit{und-pred} \\ \text{CONTENT} \begin{bmatrix} \textit{und-rel} \\ \text{UNDERGOER } \boxed{1} \end{bmatrix} \\ \text{ARG-ST} \quad \langle \ldots, \text{NP:}\boxed{1}\,(,\text{XP} \ldots) \rangle \end{bmatrix}$$

(b) The type *und-pred*

Figure 2: The *act-pred* and *und-pred* linking classes

Third, the metatheoretical constraint on the relationship between the hierarchy of semantic relations and the hierarchy of predicator types stated in (2) ensures that *because* the semantic relation of *move* is a subtype of *act-und-rel*, *move* will necessarily be a subtype of *act-pred* and *und-pred*. The required correspondence between the semantic and predicator hierarchies is illustrated in Figure 3.

(2) THE SEMANTIC SUBTYPE LINKING CONDITION
If *s* is a type in the semantic relations hierarchy and there exists a type in the word class hierarchy with CONTENT value of type *s*, then there exists a type *s-p* in the word class hierarchy with CONTENT value of type *s* such that every type in the word class hierarchy with CONTENT a subtype of *s* is a subtype of *s-p*.



(a) Semantic relations (b) Syntactic hierarchy

Figure 3: Homomorphism between semantic relation types and linking types

Together these thee constraints ensure that all English verbs whose situational meaning can be categorized as a subtype of *act-und-rel* will realize their arguments the same way.[1]

Despite the advantages of embedding a linking theory within a hierarchical lexicon detailed in Davis and Koenig (2000), Koenig and Davis (2001), and Davis (2001), there are at least three shortcomings of this approach. First, even though the attributes ACTOR and UNDERGOER are part of the semantic content of *move*, they are not semantically motivated attributes. Rather, their model-theoretic correlates are disjunctions of semantic properties, at least one of which holds of the referents of their values. Actors, for instance, may be volitional entities *or* causes, *or* impingers, and so forth. The main motivation for positing such attributes is the increased ease with which linking constraints can be stated. In that sense, the attributes ACTOR and UNDERGOER (and other attributes, as well) partially function as syntactic diacritics, as Ackerman and Moore (2001) mention. They violate what we call the *Transparency Principle*, which we state as follows:

Principle 1 (Transparency Principle) *Linking constraints must be stated in terms of semantically natural classes of properties of situations.*

The same shortcoming, as far as we can see, plagues the notions of ACTOR and UNDERGOER used in Role and Reference Grammar (Foley and Van Valin (1984)). Likewise, Pinker's (1989) resort to semantically arbitrary differences in *lexical semantic representations* can be seen as introducing syntactic diacritics where they

[1] At least for "regular" verbs. The situation is different with verbs that idiosyncratically require a PP complement.

do not belong (see Davis and Koenig (2000a)). In all such cases, linking constraints crucially rely on semantically unmotivated devices that are only posited to make sure linking constraints properly apply. As such they introduce into semantic representations information that is best left out of it.[2]

Second, the principle in (2), which is crucial to ensuring that all (transitive) words having the right meaning will realize their arguments the right way, is theoretically unsatisfying. It embodies the logic behind linking regularities, namely that all words which denote a situation-type that belongs to the appropriate semantic category should link their arguments the same way, up to syntactic idiosyncrasy. As such, the principle should be part of the grammar of languages. But it cannot be represented within the logical formalism underlying HPSG grammars. Rather, it constitutes a meta-grammatical statement on a required higher-order similarity between two type hierarchies which has no clear logical place within HPSG.

Third, the types *act-pred* and *und-pred* violate the constraints on the introduction of types discussed in Meurers (2000). Types should only be posited for linguistic objects which bear some distinct properties from other linguistic objects. They should not simply serve to select the right kind of feature structures to which constraints must apply. Otherwise, the introduced types only duplicate categories of linguistic objects introduced elsewhere in the grammar. To take an extreme example, one should not introduce a type of *nominate-noun* simply to insure that nouns whose case is nominative bear the right inflectional suffix, since the category of nominative nominals is already selected by the HEAD feature value in (3). In other words, the type *nominate-noun* is redundant, since it serves to pick a class of linguistic objects, which the head value in (3) already selects.

(3) $\begin{bmatrix} \textit{noun} \\ \text{CASE} \;\; \textit{nom} \end{bmatrix}$

Now, the types *act-pred* and *und-pred* bear no distinct properties; they simply select words whose semantic content is a relation of type *act-rel* and *und-rel*, respectively. In other words, they are only posited to ensure that words whose content is of type *act-rel* or *und-rel* link their actor argument correctly (and similarly, for other predicator types). These types violate Meurers' constraint on type introduction: They unnecessarily duplicate information already encoded in another part of the grammar.

Now, the main motivation for these three undesirable consequences lay in the logical formalism then widely used to write grammatical constraints in HPSG (basically, typed feature structures, as discussed in Carpenter (1992)). Implicational constraints of the form 'All words whose meaning is ... will ...' simply cannot be encoded because of the absence of negation (and quantification) within these languages (see Keller (1993) on that issue and Davis (2001) who remarks on this

[2]The Thematic Hierarchy, see Jackendoff (1972), Bresnan and Kanerva (1989), Grimshaw (1990), and Alsina (1992), among others, and Dowty's (1991) Proto-roles do not succumb to this difficulty, as they are explicitly recognized as interface constructs. But as Davis and Koenig (2000b) and Davis (2001) argue, other problems plague these constructs.

issue too). Implicational constraints in this formalism can only be indirectly modeled through the logic of inheritance.[3] But this has two unfortunate consequences. First, it leads to a multiplication of the number of needed types in case of disjunctive statements like the ones informally stated in (4).

(4) a. If a word has an argument that is entailed to be volitionally involved or a cause, or ..., that argument is realized as the subject of its active form.

b. If a word has an argument that is entailed to be undergoing a change of state, or impinged upon, ..., that argument is realized as the object of its active form.

Since such conditional statements are modeled through inheritance relations between subtypes and supertypes, to insure that verbs which have *both* an argument that bears one of the properties mentioned in the antecedent of (4a) *and* an argument that bears one of the properties mentioned in the antecedent of (4b) link appropriately both arguments, we need to define at least as many types as the product of the number of properties mentioned in each antecedent, i.e. a *volitional-affected-rel*, a *notion-affected-rel* and so forth, one for each combination of properties of the denotata of the verb's relevant argument positions, so that all verbs whose arguments denote participants with such properties will inherit their semantic content from the appropriate relational type. This multiplicative effect, of course, increases in the case of three place predicates. The solution proposed in Davis and Koenig (2000), Koenig and Davis (2001), and Davis (2001) is to define a single argument class for each antecedent, the value of ACTOR and UNDERGOER, and define the constraints in terms of the values of these semantically unmotivated attributes.

The second unfortunate consequence of relying solely on inheritance to model implicational linking constraints is that in and of itself, positing a type *act-pred* does not exclude the possibility that a verb which has an argument bearing one of the proto-agent entailments is not a subtype of *act-pred*, and hence would incorrectly allow its "actor" argument to be linked to the object position. To exclude this possibility, Davis and Koenig (2000) and Davis (2001) are forced to posit the meta-grammatical constraint in (2).

Since the problem lies with the fact that implicational constraints are exclusively modeled through type-inheritance, the solution is quite simple, namely adopting a formalism for writing grammars that allows for true implicational statements. The RSRL language described in Richter (2000), expanding on King's (1989) SRL, is such a language. It allows us to model conditional logic through both implicational statements[4] and type inheritance; we can then recast linking constraints in a way that avoids the three problems we mentioned.

[3]This is a slight simplification, as Carpenter also briefly discusses recursive type constraints systems. But, HPSG scholars typically have not made use of such systems, as far as we know.

[4]Strictly speaking, the meaning of implications, like all descriptions in RSRL, is not truth-conditional. We use this inaccurate way of speaking for expository purposes only. Nothing crucial hinges on this simplification.

2 How to achieve semantically transparent linking

2.1 Background constraints

First, we introduce model-theoretically transparent classes of relations, one for each relevant entailment. In place of the disjunctive *act-rel* and *und-rel*, and ACTOR and UNDERGOER, we postulate semantic relations based on individual characteristic entailments, since implicational statements directly relating lexical semantic properties to subcategorization properties render pseudo-semantic attributes like ACTOR and UNDERGOER unnecessary. Three such relations and their model-theoretic interpretations are represented in (5) below.[5]

(5) $\begin{bmatrix} \textit{cause-rel} \\ \text{CAUSER} \quad x \end{bmatrix}$ denotes the class of situations that include a participant who is the referent of the value of CAUSER and who causes a change-of-state in another participant.

(6) $\begin{bmatrix} \textit{volitional-rel} \\ \text{VOLITIONAL} \ x \end{bmatrix}$ denotes the class of situations that include a participant who is the referent of the value of VOLITIONAL and who is volitionally involved in the situation.

(7) $\begin{bmatrix} \textit{ch-of-st-rel} \\ \text{CHANGES-STATE} \ x \end{bmatrix}$ denotes the class of situations in which the referent of the value of CHANGES-STATE is an entity changing state as a result of the event.

Second, to prevent linking from needlessly applying to all roots and stems, e.g., to the verbal stems in derived nominals such as *runner* or *revocation*, we must declare the attribute ARG-ST to only be appropriate for linguistic objects of type *word* (at least in languages like English).[6] Llinking constraints can now only apply to words. But we now need a way to infer the presence of certain elements on the ARG-ST list given the semantic content of words.

The constraints in (8) and (9) are an initial attempt to accomplish that. (ARG in these formulas functions as a variable over semantic roles names.) Only two constraints like those in (8) and (9) are needed. Davis and Koenig's (2000a)'s KEY hypothesis on the structure of lexical semantic representations is correct ensures that the semantic decomposition of lexical entries' semantic content never goes deeper than one level.[7]

The first constraint says that for each of the arguments in a word's CONTENT, there must be a member of the ARG-ST list whose semantic content corresponds

[5] X in the diagrams stands for an unspecified value and is only used for purposes of exposition.

[6] We owe this suggestion to Jeff Runner and Raul Aranovich.

[7] The constraints in (8) and (9) are simplified in one important respect. In some cases the value of a verb's semantic role does not correspond directly to the semantic content of a member of the ARG-ST list, but rather to the value of an argument of that semantic content. This will occur when the relevant member of the ARG-ST list is a PP whose prepositional head is semantically potent and encodes a supertype of the meaning of the verb, as discussed in Wechsler (1995a) and Davis (2001). Nothing substantial hinges on this simplification.

to that argument. The second constraint says that for each argument of these arguments, there also is a member of the ARG-ST list whose semantic content corresponds to that argument.

(8) $\begin{bmatrix} \text{CONT} & \left[\text{ARG } \boxed{1}\right] \\ \text{ARG-ST} & \boxed{2} \end{bmatrix} \Rightarrow \exists \boxed{3}\,(\text{member}(\boxed{3}, \boxed{2}) \wedge \boxed{3}\left[\text{CONTENT } \boxed{1}\right])$

(9) $\begin{bmatrix} \text{CONT} & \left[\text{ARG } \left[\text{ARG } \boxed{1}\right]\right] \\ \text{ARG-ST} & \boxed{2} \end{bmatrix} \Rightarrow \exists \boxed{3}\,(\text{member}(\boxed{3}, \boxed{2}) \wedge \boxed{3}\left[\text{CONTENT } \boxed{1}\right])$

These constraints are strong. As formulated, they require that we confront phenomena such as the following:

- Denominal verbs, with arguments incorporated, in such cases as *butter*, *spit*, *jail*, *knife*, *juice*, and *summit*. If these verbs mean something like, e.g. "put in jail", "remove juice from", and "reach the summit of", then why do the nouns these verbs are derived from not on the ARG-ST lists of the respective verbs, since the arguments are plausibly present in the CONTENT?

- Optional arguments, such as the understood objects of *read* and *sew*, and omissable PP complements of verbs such as *cover (with)*, *remove (from)*, and *explain (to)*, which seemingly require these arguments at a semantic level, even when not overtly present.

- More generally, many verbs denote types of actions that necessarily occur at a place and time or involve other entities (e.g., in spitting, there is a mouth involved) that are never denoted by the verb's syntactic arguments, though they may be realized as adjuncts.

Some of these difficulties (perhaps all of them) can be overcome by distinguishing the value of CONTENT from a more general conceptual structure, which is not necessarily linguistic. In CONTENT, only the "linguistically relevant" arguments are present (this is very close to Pinker's (1989) position, as distinguished from Jackendoff's (1990) claim that there is only a single, unified level of conceptual structure). This move is potentially circular, however. We need independent criteria for determining what is linguistically relevant before we can explain away all the cases where an argument happens not to be syntactically realized.

We see at least two means of dealing with these issues. One is to say that the arguments are present in the CONTENT, but something precludes the constraints in (8) and (9) from applying. For instance the values of the attributes in question might be of a different type, say "non-discourse-referential"—by which we mean that they do not introduce a discourse referent in the discourse model—and that "non-referential" nominal indices cannot be associated with members of the ARG-ST list.[8] This approach might also be generalized to lexically "incorporated" ar-

[8] See Koenig and Mauner (1999) for arguments that the unexpressed "agents" of short passive and what Fillmore (1986) calls indefinite null anaphors, more generally, do not introduce referents in the discourse model.

guments, such as *butter* and *spit*. Technically, the constraints in (8) and (9) would need to be modified so that they only apply to values of ARG attributes that are "discourse-referential", as shown in (10) and (11).

(10) $\left[\begin{array}{ll}\text{CONT} & \left[\text{ARG } \boxed{1}\textit{disc-ref}\right] \\ \text{ARG-ST} & \boxed{2}\end{array}\right] \Rightarrow \exists\boxed{3}\,(\text{member}(\boxed{3}, \boxed{2}) \wedge \boxed{3}\left[\text{CONTENT } \boxed{1}\right])$

(11) $\left[\begin{array}{ll}\text{CONT} & \left[\text{ARG } \left[\text{ARG } \boxed{1}\textit{disc-ref}\right]\right] \\ \text{ARG-ST} & \boxed{2}\end{array}\right] \Rightarrow \exists\boxed{3}\,(\text{member}(\boxed{3}, \boxed{2}) \wedge \boxed{3}\left[\text{CONTENT } \boxed{1}\right])$

The second tack is the one mentioned earlier—distinguishing between the linguistically relevant semantics of CONTENT and a more general conceptual structure. We believe that there is some value in this approach, despite the difficulties in formulating conditions for linguistic relevance. Note that the lexical semantic representations assumed in Koenig and Davis (2001) or Davis (2001) already adopt this strategy when minimalizing the amoung of lexical decomposition involved in lexical semantic representations. They assume that only decompositions that are morphosyntactically relevant need be represented in the value of the CONTENT attribute of lexical entries. At least for some of the cases mentioned earlier, e.g., *butter* or *juice*, this strategy would lead to the conclusion that the semantic arguments are not part of the lexical entry's CONTENT. This same strategy would, in other cases, lead to a different conclusion. For instance, the need to specify what "figure" the location PP in (12) is predicated of suggests that the verb *spit* includes that figure in its semantic CONTENT.

(12) Don't spit into the soup.

Aside from this general strategy for deciding whether a semantic argument is the value of an attribute in a lexeme's CONTENT, there might be independent reasons for not including some information in the lexical semantic representation of words. This is the case for the time and place at which events occur, as argued in Koenig *et al.* (2003). Space does not permit us to fully resolve the difficult issue of exactly how these challenges to the constraints in (8) and (9) are best met.[9] These brief remarks should suggest several plausible avenues to achieve this proper restriction and we now turn to yet one more set of constraints that linking constraints rely on.

We posit the default canonical realization rule in (13) (together with a few others) to help infer the part-of-speech category of members of the ARG-ST list (see Pesetsky (1982) and Langacker (1987) for the notion of canonical realization principles). The constraint in (13) says that, if the semantic content of a member of the ARG-ST list is a nominal index (basically, the equivalent of an objectual discourse referent in DRT), then the part-of-speech of that argument will be nominal.

[9]Our brief discussion also does not address either the issue of words which obligatorily select expletives, such as *falloir* 'must' in French and whose stems must include some argument-structure information, even if not in the form of an ARG-ST list member.

(13) $\left[\text{ARG-ST}\ \left\langle \ldots \boxed{1}\left[\text{CONTENT}\ \left[\text{INDEX}\ \textit{nom-index}\right]\right]\ldots \right\rangle\right]$
$\Rightarrow \left[\text{ARG-ST}\ \left\langle \ldots \boxed{1}\left[\text{HEAD}\ \textit{/noun}\right]\ldots \right\rangle\right]$

2.2 Linking constraints

Now that we have shown how to represent implicational logic using both type inheritance and truly implicational constraints as well as introduced the relevant lexical semantic representations, and a few constraints on the relation between semantic and syntactic arguments and the default part-of-speech of the syntactic arguments realizing some semantic type, we can state the linking constraints needed for English, at least for direct syntactic arguments. As will be clear, the constraints are now somewhat trivial and few in number. The linking constraint for verbs whose semantics involves a causer, like transitive uses of *move* in (1), is shown at the top of Figure 4. The constraints for verbs with semantics involving a volitional agent and for verbs whose semantics involve a participant having a mental representation of another participant are stated below.

$$\begin{bmatrix}\text{CONTENT}\ \textit{cause-rel}\\ \text{ARG-ST}\ \ \langle \text{NP}, \ldots \rangle\end{bmatrix} \Rightarrow \begin{bmatrix}\text{CONT}\ \ \left[\text{CAUSER}\ \boxed{1}\right]\\ \text{ARG-ST}\ \langle \text{NP:}\boxed{1}, \ldots \rangle\end{bmatrix}$$

$$\begin{bmatrix}\text{CONTENT}\ \textit{volit-rel}\\ \text{ARG-ST}\ \ \langle \text{NP}, \ldots \rangle\end{bmatrix} \Rightarrow \begin{bmatrix}\text{CONT}\ \ \left[\text{VOLITIONAL}\ \boxed{1}\right]\\ \text{ARG-ST}\ \langle \text{NP:}\boxed{1}, \ldots \rangle\end{bmatrix}$$

$$\begin{bmatrix}\text{CONTENT}\ \textit{notion-rel}\\ \text{ARG-ST}\ \ \langle \text{NP, NP}, \ldots \rangle\end{bmatrix} \Rightarrow \begin{bmatrix}\text{CONT}\ \ \left[\text{EXPERIENCER}\ \boxed{1}\right]\\ \text{ARG-ST}\ \langle \text{NP:}\boxed{1}, \ldots \rangle\end{bmatrix}$$

Figure 4: The linking constraint for causal, volitional, and experiencer verbs

The constraints say that if an argument of the relation denoted by a predicator is a cause, a volitional entity, or an entity having a mental representation of another entity, then, the expression of this argument corresponds to the first member of the ARG-ST list. Because the implicational statements in Figure 4 behave logically (to simplify a bit) like the material conditional, any feature structure that satisfies the antecedent will necessarily satisfy the consequent. There is therefore no need for the meta-grammatical constraint in (2) anymore. That all verbs whose CONTENT includes a relation which is a subtype of *causal-rel* must link their causal argument to the first member of their ARG-ST lists simply falls out from the logical behavior of the type hierarchy and implicational statements. What was an extra grammatical constraint has now become a logical consequence in the logical formalism through which HPSG grammars are written.

In the proposed new approach to linking, there will, therefore, be one implicational constraint for each characteristic entailment in the sense of Koenig and

Davis (2001). This will clearly result in an increased number of linking constraints for linking the semantic roles corresponding to the old ACTOR attribute, but, because each implicational statement's "truth" is independent of the "truth" of other implicational statements, no multiplicative effect and loss of generalization arises. Positing separate linking constraints for volitional agents and causers does not require multiplying linking constraints when linking of both "proto-agents" and "proto-patients" (or linking of three-place predicates) is considered. The increase in number of linking constraints is simply the minimum needed to avoid the use of semantic attributes as syntactic diacritics and abide by the Transparency Principle. We can therefore truly base linking entirely on the atomic model-theoretic properties of participants without running the risk of having to repeat the constraints for "proto-agent" linking when linking "proto-patient" and other arguments. In fact, given (default) canonical realization principles as in (13), we can dispense with any implicational linking constraint to replace the UNDERGOER linking class in Davis and Koenig (2000b). Undergoers are simply participants which, because of their semantic type, are, by default, realized as nominal syntactic arguments, i.e. as some NP member of the ARG-ST list, by the constraints in (8) and (13). We do not need to specify *where* on the ARG-ST list, these NPs are. They cannot be first, because of the constraints listed above in Figure 4. They will, as a consequence, be the last NP on the list in the case of the transitive verbs. They will too, in the case of ditransitive verbs, given the linking constraint for ditransitive verbs stated in Figure 5 (adapted from Davis and Koenig (2000b)) and similar ones for other semantic uses of the ditransitive valence in English, which insures that the recipient of transfer of possession verbs is linked to the second member of the ARG-ST list.

$$\begin{bmatrix}\text{CONTENT} & \textit{transfer-possess-rel}\\ \text{ARG-ST} & \langle \text{NP}, \text{NP}:\boxed{3}, \text{NP}\rangle\end{bmatrix} \Rightarrow \left[\text{CONTENT}\left[\text{EFFECT}\left[\text{POSSESSOR}\ \boxed{3}\right]\right]\right]$$

Figure 5: The linking constraint for ditransitive verbs.

Although linking constraints for a single "argument position" will be more numerous in this revised approach to linking (there will be more than one linking constraint for proto-agents and proto-recipients, to speak loosely), each linking constraint now obeys the semantic transparency principle. There are two further important consequences of this revised linking theory. First, each linking constraint only concerns itself with a single property of participants in the described situations, since the constraints' antecedent now only mention semantic relations identified by a single property of one of their arguments. As such, our linking constraints abide by the hypothesis argued for in Koenig and Davis (2000) and stated below.

Hypothesis 1 (Singleton Property Hypothesis (SPH)) *A single characteristic entailment of the denotation of a semantic attribute's value is sufficient to determine its linking.*

Contrary to the claim put forth in Dowty (1991) and Ackerman and Moore (2001) that linking constraints must rely on comparing the cardinality of sets of participant properties, Koenig and Davis argue that determining the linking of semantic arguments is simpler. Knowing whether an argument bears *one* of a relatively small set of properties (between ten and twenty, see Carlson (1998)), is sufficient to determine its syntactic realization.

Second, the proposed new linking constraints also restrict the range of permitted lexical semantic representations. For example, the first two constraints in Figure 4 both require a certain type of participant to be realized as the first element on the ARG-ST list. Thus, if both semantic types apply to a situation type, the participants linked by the two rules must be one and the same, as shown in Figure 6. This effectively performs the same task of grouping these participants that was performed by treating ACTOR as a disjunctive attribute.

$$\begin{bmatrix} \text{CONTENT} & \begin{bmatrix} \textit{cause-volit-rel} & \\ \text{CAUSE} & \boxed{1} \\ \text{VOLIT} & \boxed{1} \end{bmatrix} \end{bmatrix}$$

Figure 6: Situation involving volitional causes

To conclude, this paper shows how to achieve complete semantic transparency of linking constraints within HPSG by relying both on inheritance hierarchies and implicational statements. Such an approach provides the means to capture the semantic generalizations which underlie linking constraints without the need to introduce unmotivated semantic attributes. It also preserves the insights of Davis and Koenig (2000a), Davis and Koenig (2000b), and Koenig and Davis (2001). In particular, our revised linking theory can incorporate as is the hypothesis that only non-modal situation information of the KEY elementary predication is relevant to the linking of direct arguments. We have also illustrated some of the potential benefits of switching from the Feature-Logic approach to grammar formalism adopted in Carpenter (1992) to the more recent RSRL approach. Interestingly enough, the increased benefits in the linguistic modeling of linking constraints from countenancing both inheritance-based and implication-based models of conditional logic echo some of the discussions on the speed vs. generality trade-off of so-called path-based and rule-based inferencing in Knowledge Representation and Reasoning systems (see Shapiro (1991))

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