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The Semantics of Possession in Natural Language and Knowledge Representation

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Abstract

The semantics of possession is explored in a representative set of languages to evaluate two contemporary theories. It is evidenced that the theories describe different aspects of the universal possessive system, and that both provide relevant theoretical constructs for the vocabulary of linguistic typology. Our findings also have consequences for knowledge representation, and in the appendix, our new vocabulary is employed in the analysis of related linguistic phenomena.

Keywords: possessives, semantics, cross-linguistic comparison, knowledge representation

1. Introduction

The surface realization of possessor-possessum relationships

(possession) varies across languages and many different strategies are employed in marking possessives, including affixation, adpositions and classification; see Croft (1990: 28-33) for a brief overview. Even closely-related languages and dialects sometimes differ dramatically in their configuration of possessives.[1] This paper explores the semantics of various possessive constructions in a representative set of languages and tries to extract some universal principles governing the semantics of possession.

The languages considered here include English (since most of the literature which is addressed here applies rather specifically to English), German, Hebrew, Hocak, Italian, Japanese, Norwegian Bokmål, Russian and Yucatec Maya. Data is imported from a wider set of languages, incl. Indonesian, Madurese and Pipil, when needed.

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[1] The languages of Mainland Scandinavian, for instance, differ a lot in their realization of possession. While Standard Danish and Standard Swedish only have genitival possessives, Norwegian Bokmål has a genitival possessive, a standard prepositional possessive and a possessive marked by a pronoun which is anaphoric to the possessor; see (4d). This last construction is also found in Western Jutlandic, a dialect of Danish, the only difference being that the pronoun is reflexive in Norwegian and not in Western Jutlandic.

(1) John hans bil
John his car
'John's car'

See Delsing (1993) for further variation at the dialectal level in Mainland Scandinavian. In addition, while Western and Central Asturian has a genitival possessive and a standard prepositional one, Easter Asturian only has the former (Lorenzo 1998). The two forms are presented here with data from Western and Central Asturian:

(2) un carru de mieu
a cart of mine
'a cart of mine'

(3) el mieu carru
the my cart
'my cart'

All of these languages have multiple ways of expressing possession, and the various constructions may not be exhausted by our exploration. Some prototypical ways of expressing possession in these languages are mentioned, however, and each construction is carefully analyzed where it introduces semantic effects not previously attested. Our coverage of English possessives includes, for instance: the genitival possessive, the standard prepositional possessive, the double possessive, and the predicative (genitival) possessive.

As is often mentioned in the literature, contemporary theories of possessive semantics come in two flavors. Sometimes these are referred to as split theories and uniform theories (e.g., Partee & Borschev 2003). The next section briefly summarizes a representative split theory account of the English possessive system. It is a reasonable starting point, since split theories are historically prior to the uniform approaches, at least in their current designs. The following sections present a representative uniform theory and evaluate the theories' success on explaining the cross-linguistic data.

2. Split Theories

The split theories (e.g., Barker 1995, Partee 1997) split the class of possessives into lexical possessives and extrinsic possessives. Lexical possessives occur when the possessum phrase is occupied by a derived nominal, a kinship term, a body part term, a generalized part/whole distinction or an arbitrary relational noun.

If the head of the possessum phrase belongs to the class of nouns which license lexical possessives, the possessive phrase is often ambiguous between the lexical and the extrinsic reading. Is this the case for all the English possessive constructions? If Stockwell et al. (1973) are to be believed, the answer is a clear "no". In fact, only the genitival possessive is structurally ambiguous on their judgments:

(1) a. Shakespeare's knife
b. *the knife of Shakespeare
c. the knife of Shakespeare's
d. (this knife is) Shakespeare's
e. Shakespeare's sister
f. the sister of Shakespeare
g. *the sister of Shakespeare's
h. (this sister is) Shakespeare's

In (1g) and (1h), the "*" marks the reported unacceptability of the lexical readings. The findings are presented in small tables throughout the rest of this paper. Senses are listed as columns and the check marks indicate that these senses are possible for the expression or construction in the left-most column of the row.

Constructions	Lexical Reading	Extrinsic Reading
Genitival Possessive	+	+
Standard Prepositional Possessive	+	
Double Possessive		+
Predicative Possessive		+

2. Uniform Theories

The uniform theories argue that the distinction between lexical possessives and extrinsic possessives is irrelevant, and that all possessives should rather be seen as lexically derived (e.g., Partee & Borschev 1998, Vikner & Jensen 2001). The extrinsic readings of (1a) are instead derived from the qualia structure of the possessum phrase, ignoring certain extra-semantic readings which are only

possible in restricted contexts. In fact, this is supposed to always be the case in the examples labeled extrinsic possessives above. Qualia structure is by now a well-known theory about the organization of dependent types in the lexicon. In a rather naïve version of standard qualia theory (e.g., Pustejovsky 1991), the possessum phrase of (1a) would have the qualia structure:

[**knife** ,
QUALIA […,
TELIC **cut**,
AGENTIVE **manufacture**]]

The telic and agentive qualia are supposed to be lexicalized information about the referent's purpose and origin. Several things are omitted from our representation, incl. formal and constitutive qualia, modality and, more importantly, linking. On these issues, see Pustejovsky (1998), Vikner & Jensen (2001), and Søgaard (2004).

The major point here is that the possessum phrase lexically specifies a set of possible readings. In (1a), these can be paraphrased as 'the knife for Shakespeare to use (to cut)' and 'the knife Shakespeare has made'. On split theories, these are collapsed into the extrinsic reading (which is then to be contextually inferred). Vikner and Jensen (2001) argue that the extrinsic reading is inadequate, since it blurs the distinction between truly contextually inferred readings and qualia-driven ones.

Qualia-based uniform theories inherit the problem of standard qualia theory, e.g., how to define the qualia of non-artifacts. In this paper, these problems are ignored, and the examples we use to evaluate the split theories and the uniform ones will primarily be chosen from the domain of artifacts. (2a-d) are used to test the semantic differences between the possessives of English, as from the perspective of uniform theories:

(2) a. Shakespeare's book
b. the book of Shakespeare
c. the book of Shakespeare's
d. (this book is) Shakespeare's

None of these possessive phrases are unacceptable. This indicates that on the split view, *book* must belong to the class of nouns that license lexical possessives. On qualia-based uniform theories, several interesting senses are derived:

- 'the book Shakespeare has written'
- 'the book for Shakespeare to read'
- 'the book about Shakespeare'

On the first reading, the possessor has agency in the agentive event of the possessum, while on the second, it is potential agency wrt. to the telic event. The third reading differs a bit. It could be said that the possessor occupies the role of the (default[2]) argument of **book**, or it could be said that the possessum phrase occupies different semantic roles wrt. the telic events on the second and the third reading (see e.g., Søgaard 2004). Call the readings, respectively, Q_A, Q_{T1} and Q_{T2}:

Constructions	Q_A	Q_{T1}	Q_{T2}
Genitival Possessive	+	+	+
Standard Prepositional Possessive	+		+
Double Possessive	+		
Predicative Possessive	+		

[2] The notion of default arguments is introduced in Pustejovsky (1991) and is supposed to identify an optional argument which is part of the logical make-up, but not necessarily syntactically realized.

The notion of potential agency is very similar to prototypical possession. Per Anker Jensen (p.c.) has suggested to me that in fact, the linguistically adequate notion in these cases is one of possession.

3. Some Empirical Data

In the next sections, cross-linguistic data is considered. A few (randomly chosen) examples were picked for comparative reasons. The possessums still—like **knife**—pertain to the sphere of artifacts. The first concept is **book**. The next is **food**. These concepts are supposed to be largely universal. In other words, most languages are supposed to adopt the qualia structures presented here (still in a quite simplistic format):

[**book** ,
QUALIA […,
TELIC **read**,
AGENTIVE **write**]]
[**food** ,
QUALIA […,
TELIC **eat**,
AGENTIVE **cook**]]

Are any of these concepts realized as relational nouns? None of the languages in question seem to realize **food** as a relational noun, while the status of some of the realizations of **book** is somewhat unclear. Unfortunately, there are no universally applicable tests which distinguish relational nouns from non-relational ones. Baker (1978) proposes to use the English *one* as an anaphor for the N'; this is of course only possible with modifiers, e.g.:

(3) a. The book by Shakespeare is longer than the one by Novalis.
b. *The book of Shakespeare is longer than the one of Novalis.

Other tests rely on indirect anaphora (Barker, 1995). Unfortunately, these provide no direct evidence about the modifier-argument status of the possessor. Another question to address before investigating the actual data is what meanings to associate with Q_A, Q_{T1} and Q_{T2} for **food**? Q_A corresponds to the paraphrase 'food which p made' (where p is the possessor), while Q_{T1} corresponds to 'food for p to eat'. There seems to be no equivalent of Q_{T2}. If the realization of **book**, at least in English, is relational, this may explain why Q_{T2} was evident in the context of books. The reading may be lexical, rather than qualia-driven. It is interesting for the evaluation to see if Q_{T2} is available cross-linguistically in this context. If not, then on the split theories, it is implied that **book** in that particular language is realized as a non-relational noun.

3.1. Italian, Japanese, and Norwegian Bokmål

Italian has a standard prepositional possessive and a definite and unmarked possessive which is very interesting, but also fairly restricted, and which is therefore not discussed here. Japanese has a postpositional possessive, while Norwegian Bokmål has both a genitival possessive, a standard prepositional possessive and a postpositional possessive (with a reflexive pronominal postposition).[3]

[3] In Colloquial German, a similar construction is found:

(1) John sein Auto
John.DAT his car
'John's car'

In creole Negerhollands, the same construction is found with a non-reflexive pronoun, as in Western Jutlandic. Similarly for other creoles, incl. Hiri Motu, Indo-Portuguese, Karipuna Creole French, Louisiana Creole French, and Mauritian

In addition, all three languages have pronominal possessives. Norwegian Bokmål has both prenominal and postnominal pronominal possessives, and interestingly, with the same set of pronouns. The non-pronominal constructions are exemplified below, respectively:[4]

(4) a. il libro di Shakespeare (Italian)
the book PREP Shakespeare
'Shakespeare's book'
b. Sheekusupia no hon (Japanese)
Shakespeare CL food
'Shakespeare's book'
c. boka til Shakespeare (Norwegian)
book PREP Shakespeare
'Shakespeare's book'
d. Shakespeare sin bok
Shakespeare his book
'Shakespeare's book'

The pronominal possessives with **food** as possessum (pronouns are rare in Japanese, so no data is supplied for Japanese):

(5) a. il mio pasto (Italian)
the my food
'my food'

Creole French (Heine & Kuteva 2001). Interestingly, the word order of the construction is reversed in certain Amerindian languages, e.g. Pipil (Heine & Kuteva 2001) in (2). This is interesting because various linguists have analyzed constructions such as (1) as a kind of topicalization.

(2) i- ih- i: x ne siwa: pil
her PL eye the girl
'the girl's eyes'

[4] The following abbreviations are used in this paper: PREP = preposition; CL = classifier; DEF = definite; PL = plural; SG = singular; PN = proper name; 3 = third person; POSS = possessive.

b. min mat (Norwegian)
my food
'my food'
c. maten min
food.DEF my
'my food'

In addition, we added the predicative (genitival) possessive. The predicative possessive of Norwegian Bokmål behaves syntactically similar to the Italian construction (but they are not quite equivalent; see below):

(6) Questo libro è di Shakespeare.
this book is PREP Shakespeare
'This book is Shakespeare's.'

The data has been evaluated with informants, and certain judgments were adopted from the literature; more specifically, Storto (2000) for the Italian predicative possessive and Kikuchi and Sirai (2003) for the postpositional possessive in Japanese.

Language	Constructions	Q_A	Q_{T1}	Q_{T2}
Italian	Standard Prepositional Possessive	+	+	+
	Predicative Possessive	+	+	
	Pronominal Possessive	+	+	+
Japanese	Postpositional Possessive	+	+	+
Norwegian Bokmål	Genitival Possessive	+	+	
	Standard Prepositional Possessive	+	+	
	Postpositional Possessive	+	+	
	Predicative Possessive		+	
	Pronominal Possessive	+	+	+

3.2. German, Hebrew, and Russian

Until now we have talked about predicative possessives, ignoring that these are sometimes hard to identify. This is because other possessives can be used elliptically. The surface structure of an elliptical possessive can sometimes be exactly the same as that of a predicative possessive, e.g., *This book is Shakespeare's*.

Some languages with richer agreement systems reflect this difference in their surface structure. Such languages include German and Russian.[5] Consider e.g. the following examples:

(7) a. Die Kinder sind meine.
the children.PL are mine.PL
'The children are mine.'

b. Die Kinder sind mein.
the children.PL are mine.SG
'The children are mine.'

In (7a), there is agreement, which indicates the possessive is elliptical. (7b) is on the other hand a true predicative possessive. The interpretations of these possessive constructions differ. The elliptical possessive has the same interpretation as the corresponding pronominal possessive; in particular, the lexical reading is favored. In (7b), however, only the extrinsic reading is possible. Consequently, (7b) suggests a custody fight or worse.

Since Russian has two possessive constructions, a prenominal possessive and a postnominal genitive, reflected by the nominative and instrumental forms of the possessive pronouns, of which only the postnominal genitive and the instrumental form allow lexical readings (Partee & Borschev 2003), Russian reflects the difference

[5] The data considered in this section is adopted from Partee & Borschev (2003). Their (informants') judgments are also relied on.

between elliptical and predicative possessions strongly. Ellipsis, as in (7b), is impossible with nominative pronouns, evidenced by the unacceptability of the insertion of the noun in (8):

(8) Ta stranga byla kogda-to
that.NOM country.NOM was once
moja (*strana).
my.NOM country.NOM
'That country was once mine (my country).'

(8) conveys possession, not citizenship. The citizenship reading comes from the elliptical construction, where the pronominal possessive is instrumental *moej*. In the table below, we list only the pronominal possessive and the predicative possessive of the German possessives, since these are what is of immediate relevance:

Language	Constructions	Q_A	Q_{T1}	Q_{T2}
German	Pronominal Possessive	+	+	+
	Predicative Possessive		+	
Russian	Postnominal Genitive	+	+	+
	Prenominal Possessive		+	
	Instrumental Pronominal Possessive	+	+	+
	Nominative Pronominal Possessive		+	

Hebrew is mentioned here to support the pattern above. Just like Russian, it has two possessive constructions; one which allows both lexical and extrinsic readings (9a), and one which allows only possessive (or extrinsic?) readings (9b); the data is adopted from Heller (2002). (The same pattern, roughly, was pointed out by Nikolaeva (2002) for Hungarian.)

(9) a. har-horim šel ha-psixolog
DEF.parents PREP DEF.psychologist
'the psychologist's parents'
b. horey ha-psixolog
parents DEF.psychologist
'the psychologist's parents'

3.3. Hocak and Yucatec Maya

Hocak is a Siouan language of the Mississippi Valley. The possessive system is described in Helmbrecht (2003). Syntactically, Hocak is interesting, since it is one of the few languages in which possession is expressed exclusively by juxtaposition. Semantically, however, the juxtaposed construction seems to behave much like the standard constructions of the languages we have discussed so far. Of course, this is typologically interesting, since it indicates that generalizations can be made across the possessive systems.

However, there is another aspect of the possessive system in Hocak which is truly interesting from a semantic perspective. It is possible to specify the nature of the possessive relation more precisely by compounding the possessor and possessum phrases with a transitive verb. This is called a nominalized possessive. The nominalized possessive (10b) has exactly the same syntactic status as the juxtaposed possessive (10a).

(10) a. John-gá hiratí-gá
John.PN car.DEF
'John's car'
b. John-gá hiratí haní-rá
John.PN car own.DEF
'John's car'

The suffix *-rá* realizes definiteness. The transitive verb *haní* is a

possessive verb. Hocak has three different possessive verbs. One is reserved for kinship (*hii*), another for domestic animals,[6] while the third (*haní*) is reserved for inanimate objects, incl. body parts. The pronominal possessive system also distinguishes between these three classes, i.e. the various inflections of the pronominal possessor differ according to the semantic class of the possessum.

(11) a. John-gá hiacrá
John.PN father.DEF
'John's car'

b. John-gá hací hiirá
John.PN father kin.DEF
'the father of John'

How does this relate to our previous classifications? The third kind of nominalized possessives—call them *haní*-nominalized possessives—correspond roughly to extrinsic possessives, with the important exception of body parts. Should we conclude that Hocak partition the set of lexical possessives in two, a class with kinship relations and a class with domestic animals as possessums, and that it counts body part (and part/whole) relations to the class of extrinsic relations?

Barker (1995) distinguished between derived nominals, kinship terms, body part terms, generalized part/whole distinctions and arbitrary relational nouns. I propose to collapse body part terms and part/whole distinctions, since these just seem to depend on whether the possessor is human. Generalizing over Barker's classification, one might propose to order the possessive relations hierarchically:

KINSHIP >> PART/WHOLE >> QUALIA >> OWNERSHIP

[6] Yucatec Maya has separate classifiers for domestic animals too; see below.

We exclude the derived nominals, since nominalization is a syntactic phenomenon. Using this new terminology, Hocak can be said to have one nominalized possessive that realizes KINSHIP, one nominalized form which realizes a secondary form of kinship (humans' relations to pet animals), and a third one which realizes all but kinship.[7] The juxtaposed possessive comprises both kinship and non-kinship possessive relations.

The possessive system of Yucatec Maya is even more fine-grained than that of Hocak (Lehmann 1998). Consider the following rough translations, but not quite equivalents of (5a-c):

(12) a. in w'och hàanal
my food.CL food
'the food for me to eat'
b. in mehen hàanal
my artifacts.CL food
'the food I have made'

Possession is marked by (optional) classifiers in Yucatec Maya, and the classifier system is very rich. In fact, the classifier *o'ch* derives from a synonymous realization of **food**. Consequently, *in w-o'ch* also means 'my food'. I am not certain whether this form is equivalent to only (12a) or both. The classifier *mehen* derives from the verbal lexeme realizing **make** and can be used as a general agentive classifier. The word for **cook** (the person) is *h-mèen-hanal* (roughly, 'one who makes food'). The classifiers of Yucatec Maya include:

[7] There is no empirical evidence that *haní*-nominalized possessives express Q_A -relations (QUALIA). The data in Helmbrecht (2003) is simply not conclusive in this respect.

Form	Meaning
o'ch	food
alak'	domestic animals
pak'al	things planted
mehen	things made
matan	things received
sih	things presented
man	things bought
kon	things sold
ch'ak	things cut
pay	things drawn
ch'a'	things fetched
kóol	things pulled

Yucatec Maya also has a rich system of semantic classes for nouns. The categories include artifacts, body parts, persons (roles), plants, abstract entities and others. The classifiers have certain selectional restrictions distributed across the semantic categories. The interesting aspect of this pronominal possessive system is its fine-grainedness and that the various classes of possessive relations identified by the classifiers are all extrinsic relations. The lexical possessives have a separate possessive construction: [8]

(13) a. *Tu'x yàan in x-ba'y?*
where is my bag
'Where is my bag?'

b. *Tu'z yàan u x-ba'y-il in nòok'?*
where is POSS.3 bag.REL my dress
'Where is the bag for my dress?'

[8] The notion of lexical possessives seems less adequate in the context of Yucatec Maya, since relational nouns are results of a productive morphological process, not lexicalized as such (apart from nominalizations). Partee (1997) uses the more semantic terminology of possessives introducing inherent or free relations.

The third person pronoun *u* indicates possession, just like the first person pronoun *in*. The suffix *-il* marks relational nouns. Consequently, Yucatec Maya allows you to force a relational (lexical) reading. The pronominal prepositional possessive in (13b) is syntactically similar to the *sin*-possessive of Norwegian Bokmål in (4d).

The point is that the latter construction, call it the relational possessive, works for KINSHIP and PART/WHOLE (and metaphorical extensions thereof), while the classificational possessive licenses qualia-based and possessive interpretations. In addition, a large set of the contextually inferred possessives in other languages are specified by conventional classifiers in Yucatec Maya.

Language	Constructions	KINSHIP	PART/ WHOLE	QUALIA	OWNER SHIP
Hocak	Other Nominalized Possessive	+			
Kinship	*Hanì*-nominalized Possessive		+		
	Juxtaposed Possessive			+	+
Yucatec Maya	Relational Possessive	+	+		
	Classificational Possessive			+	+

3.4. Reclassification

It is now possible to generalize over our findings. The various constructions of the test languages are related to the introduced hierarchy, and the evaluation is represented in the same table:

Language	Constructions	KINSHIP	PART/ WHOLE	QUALIA	OWNER SHIP
German	Pron. poss.	+	+	+	+
	Pred. poss.				+
Hocak	Other nominalized poss.	+			
	Hanì-nominalized poss.		+		
	Juxtaposed poss.			+	+
Italian	Std. prep. Poss.	+	+	+	+
	Pred. Poss.		+	+	+
	Pron. Poss.	+	+	+	+
Japanese	Postpos. Poss.	+	+	+	
Norwegian Bokmål	Gen. poss.	+	+	+	+
	Std. prep. Poss.	+	+	+	+
	Postpos. Poss.	+	+	+	+
	Pred. poss.		+	+	+
	Pron. Poss.	+	+	+	+
Russian	Postnom. Gen.	+	+	+	+
	Prenom. Gen.				+
	Instr. Pron. Poss.	+	+	+	+
	Nom. Pron. Poss.				+
Yucatec Maya	Relational poss.	+	+		
	Classificational poss.			+	+

In most languages, the behavior of derived nominals correspond to that of kinship terms. The Hebrew data parallels the Russian data.

On this classification, the possessive constructions of Norwegian Bokmål are also semantically similar to those of Italian. Why is that? The only reasonable explanation is the relational status of the lexemes realizing **book**. Consequently, *bok* must be non-relational in Norwegian

Bokmål. If not, either the classifications (in the sense that some additional theoretical constructs are needed to explain the data) or my informants are wrong.

Note, however, that the predicative possessives of German and Italian differ. Of course, this may reflect that the German possessive in question is pronominal, whereas the Italian one is prepositional. The difference is that the Italian predicative construction allows PART/WHOLE readings (and all readings below that in the hierarchy; see (14)), while the German predicative pronominal possessive only allows possessive readings (Partee and Borschev, 2003; this was also confirmed by my informants):

(14) *Questo coltello è di plastica.*
this knife is PREP plastic
'This knife is made of plastic.'

4. Conclusion

The terminology employed in the hierarchy seems linguistically adequate, i.e. a sound metalanguage for talking about the semantic range of possessive constructions. This is an important basis for a comprehensive study of the cross-linguistic variation of the semantics of possession in natural language. What theoretical insights have we gained wrt. the controversy between split theories and uniform theories?

Some of this dispute relates to issues of compositionality. Such issues have not been addressed here, but from a constructional perspective, this work still settles a few issues. Importantly, it was seen that there are good reasons to identify lexical readings, if we restrict the class of lexical possessives to those with kinship terms and derived nominals heading their possessum phrases. Of course, there may still be more or less uniform ways to compose the semantics. On

the other hand, it was shown that the notion of qualia *is* important for the semantics of possession, at least in some languages (our data tells us this is the case for Hocak, Italian, Russian and Yucatec Maya). Since similar studies, e.g. Søgaard (2004), have shown qualia to be important in the semantics of compound nouns (in Danish, English, Estonian and Italian), it is reasonable to conclude that QUALIA should be included in the vocabulary of a meta-language for linguistic typology. KINSHIP, PART/WHOLE and OWNERSHIP are already well-established terms of that vocabulary.

4.1. A logic of Possession

Descriptions logics were designed for knowledge representation tasks. The standard languages define terminologies and real world conditions, e.g.:

(15) a. $Father \equiv Man \cap hasChild.Person$
b. $hasChild(GeorgeBush,GeorgeWalkerBush)$

Areces & de Rijke (2001) point out the intimate relationship that exists between description logics and hybrid ones. Standard modal logics only define terminologies, not real world conditions. This is exactly how hybrid languages enrich modal ones; they add nominals, to each of which any valuation assign a singleton subset. In other words, hybrid languages add (state) constants to modal languages. In addition, the basic hybrid language includes a satisfaction operator $@_i f$ which says "jump to state i and evaluate f as true." Unlike standard modal logics, basic hybrid logic for example defines reflexivity ($@_i \neg \Diamond i$). It is in this hybrid language our logic of possession is couched.

If a description logic is constructed for knowledge representation on the basis of natural language, the important issues include whether the knowledge representation language is as inclusive as the natural

ones, and whether the same distinctions can be made. Inclusivity seems trivial when it comes to relational knowledge, which is what descriptions logics try to model, although certain philosophical questions arise with respect to type-token distinctions and infinity. Such issues are ignored here, and we only discuss the implementation of natural distinctions.

The data suggests that not only independent semantic relations are singled out by natural languages, but they also single out spans of continuums or hierarchies of semantic relations. This is the first complexity for a logic of possession. The second is that some of the possessive relations that it seems we need to express, are dependent on the possessor or the possessum. Consequently, our logic must define such dependencies.

The main difference between natural language and knowledge representation of relevance to us is of course the degree of explicitness. Natural language expressions are highly ambiguous. The obvious functional motivation for the ambiguity or polysemy of natural language is economy and creativity. Ambiguity, if it is systematic or logical somehow, reduces the vocabulary and adds generative power to natural languages even at the lexical level. In knowledge representation, it is important to be explicit. Economy is not necessarily a concern, but formal complexity is. It is not so clear, if knowledge representation can simply ignore creativity and productivity. If the formal language is interfaced with natural language, it is of course necessary to translate also novel compositions. In addition, the generative mechanisms that drive linguistic creativity may suggest natural methods and techniques for the organization of knowledge. In fact, it seems that the very relations we just identified also underlie folk taxonomic classification. The discussion below relies on Wierzbicka's (1985) research on folk taxonomies.

Let us now first consider our logic of possession. It consists of a definition of the basic hybrid language $H^@$ and an axiom set that defines the space of possession.

Definition 1 *Say there are two distinct sets of propositions (PROP) and nominals (NOM). The wellformed formulae of* $H^{@}$ *are defined by:*

$f := p|i|\neg\varphi|\varphi\vee y|\check{}f|@_i f$

where$\check{}$ *stands for any of a set of modal operators* $\{a,\check{}b,\ldots\}$.

The satisfaction definition is as follows:

- *M,w models p iff* $w \in V(p)$,
- *M,w models* $\neg f$ *iff M,w does not model f,*
- *M,w models* $f\vee y$ *iff M,w models f & M,w models y,*
- *M,w models* $\check{}f$ *iff there exists a* $w' \in M$ *s.t. wRw' & M,w' models f, and*
- *M,w models* $@_i f$ *iff M,w' models f, where* $V(i)=\{w'\}$, $i \in NOM$.

The decidability of this language comes from the fact that variables are substituted with nominals, and universal closure, not actual quantification, is employed. Basic hybrid logic is decidable in polynomial space. Global modalities are added at a cost; basic hybrid logic with global modalities is decidable in exponential time. For proofs, see Areces and Blackburn (1999). (15a) and (15b) translate into:

(16) a. $Father \equiv Man \wedge \langle hasChild\rangle Person$ where *Father, Man, Person* $\in$ *PROP*

b. $georgeBush \wedge \langle hasChild\rangle georgeWalkerBush$ where $georgeBush, georgeWalkerBush \in NOM$

The distinction between propositions and nominals reflects the distinction between the terminological and real world levels of description logics. The axiom set which defines the space of possession as presented here, includes:

(17) a. $@_i{}^n$*relation˙Kinship* → $@_i{}^n$*possessor˙j* ∨ *Person)* ∨ $@_i{}^n$*possessum˙k* ∨ *Person)* ∨ $@_l{}^n$*possessor˙k* ∨ $@_l{}^n$*possessum˙j*

b. $@_i{}^n$*relation˙ PartWhole* ∨ $@_i{}^n$*possessor˙j* ∨ $@_i{}^n$*possessum˙k* → ¬*(*$@_l{}^n$*possessor˙k* ∨ $@_l{}^n$*possessum˙j* ∨ $@_l{}^n$*relation˙PartWhole))*

c. $@_i{}^n$*relation˙j* ∨ *Qualia* → $@_j$*Agentive OR Telic*, where

(i) $@_i{}^n$*relation˙j* ∨ *Agentive* ∨ $@_i{}^n$*possessum˙*^{n}*agentive_value˙f* → $@_j f$

(ii) $@_i{}^n$*relation˙j* ∨ *Telic* ∨ $@_i{}^n$*possessum˙*^{n}*telic_value˙f* → $@_j f$

d. $@_i{}^n$*relation˙ Ownership* ∨ $@_i{}^n$*possessor˙j* ∨ $@_i{}^n$*possessum˙k* → ¬*(*$@_l{}^n$*possessor˙k* ∨ $@_l{}^n$*possessum˙j* ∨ $@_l{}^n$*relation˙Ownership))*

e. the definition of the continuum, e.g.

(i) *Possession* ↔ *Kinship_PartWhole_Qualia OR PartWhole_Qualia_Ownership*

(ii) *Kinship_PartWhole_Qualia* ↔ *Kinship_PartWhole OR PartWhole_Qualia*

(iii) …

f. $@_i{}^n$*relation˙j* ∨ *Possession* → ¬*(*$@_j i$*),* ...

(a) imposes selectional restrictions and symmetry, (b) and (d) asymmetry, and (f) imposes irreflexivity. If necessary, transitivity is easily added to the definition of kinship and part/whole relations.

It is important that hybrid logic, unlike standard modal logic, is able to talk about both terminologies and real world conditions. It seems that whereas part/whole-relations and qualia roles are usually defined at the terminological level, kinship and ownership are defined at the level of real world conditions. For instance, a **wheel** is by definition part of a car, and its function is transportation, but by ownership it is related to an individual, not a semantic type or a term.

Kinship also seems to be a relation between individuals, described by nominals, rather than types, described by propositions that denote states. This has linguistic significance. Western Indonesian languages express possession in terms of two different constructions; one which behaves syntactically like noun phrase incorporation, and which restricts the type or term associated with the possessum, and another which restricts the possessum at the token or object level (Lander, 2003). Consequently, the ability to infer both about terms and objects is necessary to encode possession in these languages too. (18) is from Indonesian, and (19) is from Madurese:

(18) ruangan konsert-nya
hall concert.3
'their concert hall'

(19) abbhi mèra-na Rahma
pepper red.3 Rahma
'Rahma's red pepper'

The logic also comes to use in defining folk taxonomies. The central question for research in folk taxonomies seems to be what constitutes a semantic class, and it is argued here that classes are in fact defined along criteria easily expressed in the logic.

Classes have subclasses and constitute taxonomic hierarchies, which are easily encoded in the propositional fragment of our logic. Secondly classes are of different kinds, i.e. natural or functional. The necessary condition for being part of a functional class is to have a compatible agentive or telic role. Consequently, in our logic classes can be identified on the basis of what propositions hold true at their <*agentive_value*> and <*telic_value*> transitions. The various classes of things are then represented by orthogonal inheritance. For illustration, **spoils** is an agentive class, while **kitchenware** is a functional one. Sometimes a class is defined by multiple roles, e.g.,

medicines and **herbs** have the same functional role, but differ in their agentive ones. Part/whole relations also seem to constitute natural classes, i.e. classes of constituent components. In sum, the logic of possession describes the most basic patterns of classification. This indicates that these patterns are in fact cognitive, not linguistic of nature, but see the section on compound nouns below for evidence that natural languages grammaticalize similar distinctions.

5. Applications

Natural language semantics and knowledge representation are of course different sciences. The logic of possession was designed to represent knowledge, but of course it can be used in natural language analysis too. The next sections are rather informal; signs are assumed to come with some meaning, and some compositional machinery is assumed.

5.1. Coordination of Possessums

The phenomenon addressed here is coordination of possessum phrases in Standard Danish. The data seems puzzling at first, but the distribution in fact fits our classification quite nicely:

(20) a. min far og søster
my father and sister
'my father and my sister'

b. mit bryst og hjerte
my chest and heart
'my chest and my heart'

c. computerens joystick og mus
computer.DEF.POSS joystick and mouse
'the joystick and the mouse of the computer'

d. *mit digt og manuskript
my poem and manuscript
'my poem and my manuscript'

The Danish first person possessive pronoun is used to refer to the possessor in (20a-d). (20a) coordinates the possessums **father** and **sister**. In Danish, these are not a fixed pair (like **father** and **mother**); so this is not what explains the acceptability of the construction. It is rather a matter of kinship. In addition, coordination of possessum phrases is allowed with body part terms. The possessum phrases in (20b) realize **chest** and **heart**. It's not a problem that we have collapsed the notions of body parts and generalized part/whole distinctions, since this applies to part/whole distinctions as well. (20c) translates 'the joystick and (the) mouse of the computer'. If the relation between possessor and possessum is QUALIA, the coordination becomes ungrammatical, however, as evidenced by (20d). Here an attempt to coordinate **poem** and **manuscript** is made.

Consequently, the analysis of (20a-d) is that *only kinship and part/whole possessums coordinate at the N' level*. If the coordination is supposed to mark the conjuncts such that they can be identified as conjuncts, this is trivial to implement. If *N'-Conjunct* denotes the set of states (or worlds) that corresponds to N'-coordinated signs, then this axiom can be added:

(g) $@_i{}^{n}$*possessum*$\cdot$ *N'-Conjunct* →
$@_i{}^{n}$*relation*$\cdot$*Kinship OR PartWhole*

5.2. Compound Nouns

Semantic theories of binominal compounds come in various flavors; see Søgaard (2004). One branch of theories argues that the semantic relation between the two constituents is contextually inferred (e.g., Bauer 1979), but it is assumed below that, on the

contrary, a set of possible relations is somehow given, whether they are transformationally derived, selected from some set of primitive and universal relations, or composed of subatomic lexical semantics. This discussion is not important here. What *is* important, however, is that some of the possible relations identified here reflect sense distinctions relevant for possessive constructions and, moreover, binominal compounds provide evidence that some of these distinctions are in fact grammaticalized and not just part of general cognition.

The similar semantics of binominal compounds and possessive constructions is well-known. (A warning sign must be put up. Compounds come in four difference classes. Only endocentric compounds are comparable to possessives; in fact, only the subset of endocentric compounds with non-metaphorical modifiers.[9] Consequently,

[9] Consider the compounds below. (1) is an appositional compound, (2) is a copulative compound, (3) is a left-headed endocentric compound with a non-metaphorical modifier, while (4) represents the right-headed version, (5) is a left-headed endocentric compound with a metaphorical modifier, while (6) is right-headed, (7) is exocentric and left-headed, while (8) is the right-headed one. Only (3) and (4) have possessive equivalents. (The data is adopted from Søgaard 2004.)

(1) bahay-kuba (Tagalog)
house-hut
'hut'
(2) bassu karu (Kannada)
bus car
'vehicles'
(3) oreh iton (Hebrew)
editor newspaper
'newspaper editor'
(4) numn numpran (Yimas)
village pig
'domesticated pig'
(5) sundalong-kanin (Tagalog)
soldier-cooked rice
'cowardly soldier'
(6) mek'inobal (Tzotzil)
mother-haze
'rainbow'

it is only this subset of binominal compounds we refer to below, not exocentric, copulative or appositional ones.) In fact, subclasses of binominal compounds of one language often systematically translate into possessive constructions of another language. For instance, German compounds with human denoting modifiers consistently translate into genitival possessives of English. Similarly, German binominal compounds with location-denoting modifiers often translate into adjective-noun combinations in Polish, while compounds with object-denoting modifiers of German translate into the Polish genitival possessive.

Evidence for grammaticalization is clearer with compound nouns than with possessive constructions, as mentioned. In the literature, a number of classes of ungrammatical noun-noun combinations have been identified in certain languages. The principles that were extracted from the data include:

- English does not allow human-denoting modifiers in endocentric constructions (Copestake & Lascarides 1997),
- Danish does not allow instrumental modifiers in qualia-based endocentric contexts, i.e., "a B which uses an A to do something or was made of someone using an A" (Søgaard 2004), and
- Estonian does not allow a compound AB to be interpreted as "a B which looks like an A" (Hiramatsu et al. 2000).

These facts are illustrated by the following data (see Hiramatsu et al. 2000, for comparable data from Estonian; the equivalent of (d) and (f) should be ungrammatical):

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(7) panawag-pansin (Tagalog)
calling instr.-attention
'one who wants attention'
(8) Romanteppich (German)
novel-tapestry
'a style of prose'

(21) a. *butcher knife
b. knife butcher
c. butcher sculpture
d. slagterkniv (Danish)
e. *knivslagter
f. slagterskulptur

(21a) and (21d) are each other's literal translations, and so forth. The ungrammaticality of (21a) is enforced by selectional restrictions, but (21e) requires reference to qualia roles. The ungrammaticality in Estonian is puzzling. Søgaard (2004) suggests to treat information about the form or contour of objects as information about qualia.

In sum, binominal compounds provide evidence for the grammaticalization of qualia structure. Coordination of possessums and various possessive constructions found in the world's languages provide evidence for the grammaticalization of a distinction between, on the one hand, kinship and part/whole distinctions and, on the other, qualia and ownership. Finally, some languages grammaticalize the internal distinction between kinship and part/whole distinctions, incl. Hocak.

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