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Preface

I am pleased to present the eleventh volume of the series *Empirical Issues in Syntax and Semantics* (EISS), which, like the preceding ten volumes of the series, is closely related to the conference series *Colloque de Syntaxe et Sémantique à Paris* (CSSP). The eleven papers included in the present volume are based on abstracts that were accepted for (and, in most instances, also presented at) CSSP 2015, which took place on 08–10 October 2015 at Université Paris 7 (`http://www.cssp.cnrs.fr/cssp2015/index_en.html`). CSSP 2015 had a small thematic session entitled *Global or genre/domain-dependent grammar?*, but since the number of papers from the thematic session submitted to the volume was low, it did not seem desirable to have two groupings of papers.

I would like to take this opportunity to thank the external reviewers, whose comments aided the authors in revising the first drafts of their papers, sometimes substantially. With their permission, the external reviewers were (in alphabetical order by column):

Chris Cummins	Jonathan Ginsburg	Philip Miller
Tim Fernando	Caroline Heycock	Manfred Sailer
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Hans-Martin Gärtner	Alda Mari	

Finally, I would also like to take this opportunity to thank both the scientific committee and the organizing committee of CSSP 2015 (`http://www.cssp.cnrs.fr/cssp2015/contact/index_en.html`) for their efforts in planning and organizing a memorable conference.

Christopher Piñón
December 2016

Syntactic Mismatch in French Peripheral Ellipsis

Anne Abeillé • Berthold Crysmann • Aoi Shiraïshi

Abstract We provide new data showing that the commonly assumed identity constraint on shared material in right-node raising (RNR), or right peripheral ellipsis, should be relaxed. RNR has always been set apart from other kinds of ellipsis in this respect, and alternative analyses have been proposed: multidominance (McCawley 1982, Bachrach & Katzir 2009) or backward deletion (Kayne 1994, Chaves 2014). The data we provide about determiner, preposition and voice mismatch, put RNR back in the family of elliptical constructions. Since RNR may also involve non constituents, and imposes syncretism on the shared material, we propose an analysis in Head-driven Phrase Structure Grammar in terms of phonological identity of meaningful material, allowing for mismatches of grammatical markers.

Keywords French · ellipsis · mismatch · HPSG · right-node raising

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1 Syntactic Mismatches in Ellipsis

Elliptical constructions come in different types: sluicing, gapping, VP ellipsis, right-node raising (RNR) (or peripheral ellipsis). They have been analyzed using syntactic reconstruction (Merchant 2001), semantic reconstruction (Dalrymple et al. 1991) or mixed approaches (Ginzburg & Sag 2001, Culicover & Jackendoff 2005).

It is well-known that syntactic mismatches may arise between the material missing in the elliptic clause (the target) and the material present in the full clause (the source): the source and the target have different syntactic categories, or different grammatical features. In (1a) there is tense mismatch between the source and the target in (1b) agreement mismatch, in (1c) voice mismatch (Hardt 1993, Kehler 2000), and, in (1d) category mismatch (Kehler 2000).

(1) a. I have looked into this problem and you should ~~look into that problem~~.
b. Paul is at home and his sons ~~are~~ at school.
c. This problem was to have been looked into, but obviously nobody did ~~look at it~~.
d. This letter deserves a response, but before you do ~~respond~~ …

In (1a) the reconstructed material would be *look into this problem*, in (1b) *are*, in (1c) *look into this problem*, and in (1d) *respond*. These mismatches argue against a deletion-and-copy approach to ellipsis. They argue for a semantic reconstruction at LF. For VP ellipsis, they have served as argument for a null complement analysis (Hardt 1993, Ginzburg & Sag 2001). For gapping, they have served as argument for a fragment analysis (Culicover & Jackendoff 2005, Abeillé et al. 2014).

Voice mismatch has been discussed for VP ellipsis (Kehler 2000, Merchant 2012) and pseudo-gapping (2a) (Miller 2014). As shown by Kertz (2013), voice mismatch is allowed (2b) unless there are contrastive topics (2c).

(2) a. The savory waffles are ideal for brunch, served with a salad, as you would a quiche. (COCA, magazine)
b. This information could have been released by Gorbachev, but he chose not to. (Hardt 1993)
c. # The incident was reported by the driver, and the pedestrian did too.

Merchant (2012) argues that no voice mismatch is possible in other kinds of ellipsis such as gapping and sluicing. No such mismatches have been reported so far for right-node raising, or peripheral ellipsis.

2 Peripheral Ellipsis

Peripheral ellipsis is usually known as RNR (Ross 1967) but involves left-peripheral material in verb-final languages (Yatabe 2001).

(3) John likes ~~bananas~~ but Mary dislikes bananas.

With pro-drop languages, a distinction should be made between peripheral ellipsis and subject or object drop (Yatabe 2001, Abeillé & Mouret 2010). For example, in French, verbs like *pouvoir* 'can' allow for null pronominal complements (4b). So (4a) can be analysed as a clausal coordination with a null pronoun in the first clause, and not as peripheral ellipsis.

(4) a. Je peux et je veux partir.
I can and I want leave
'I can and I want to leave.'

b. Je veux partir et je peux.
I want leave and I can
'I want to leave and I can.'

Abeillé (2006) also proposes to distinguish peripheral ellipsis from lexical coordination (5). In what follows, we are careful to only take examples which undisputely fall under peripheral ellipsis: involving more than lexical coordination and where the shared material is obligatory, and the first conjunct ungrammatical without it.

(5) a. [le ou la] responsable
the.M.SG or the.F.SG responsible
'the man or woman in charge'

b. Paul [apprécie et approuve] votre proposition.
Paul appreciates and supports your proposal
'Paul appreciates and supports your proposal.'

Peripheral ellipsis shows the following properties. It can occur outside coordination or dialogue (6a,b) (Williams 1990, Abeillé & Mouret 2010). It can apply to non-maximal constituents (6c) and to word parts (6d) (Chaves 2008).

(6) a. Anyone who meets really comes to like our sales people.

b. On préfère ce que fait à ce que dit un Président.
one prefers what does to what says a president
'One prefers what a President does to what he says.'

c. It was a sweet and an intelligent dog. (Switchboard corpus, Penn Treebank)

d. These events took place in pre- or in post-war Germany?

Peripheral ellipsis is usually assumed to impose strict identity conditions. As Chaves (2014) points out, inflection differences (7a), gender differences (7b), number differences (7c) and polarity differences (7d) make peripheral ellipsis unacceptable.

(7) a. * I like ~~playing guitar~~ and I will play guitar.
b. * I know that Paul ~~is leaving~~ but I don't know whether his children are leaving.
c. * Paul saved ~~himself~~, but Mary didn't save herself.
d. * Paul read ~~some book~~ but he didn't understand any book.

According to Pullum & Zwicky (1986), mismatches require syncretic forms (8b,c). When the first conjunct and the second conjunct do conflict, the syncretic form resolves this conflict.

(8) a. * I already have ~~clarified the situation~~ and you certainly will clarify the situation.
b. I already have ~~set the record straight~~ and you certainly will set the record straight.
c. Certaines agences ont déjà ~~fermé leurs portes~~ ou
certain agencies have already ~~closed their doors~~ or
vont bientôt fermer leurs portes.
will soon close their doors
'Certain agencies have already or will soon close their doors.'
(Le Monde) (Abeillé & Mouret 2010)

On the semantic side, peripheral ellipsis needs no referential identity (9a,b) but requires lexematic identity (9c,d).

(9) a. Paul buys ~~old books~~, and his brother sells, old books.
b. Do you want to meet ~~a movie star~~ or to be a movie star? (Whitman 2005)
c. # Robin swung ~~an unusual bat~~ and Leslie tamed an unusual bat. (Levine & Hukari 2006)
d. # Paul a rencontré ~~un avocat~~ et il mange un avocat.
Paul has met ~~a lawyer~~ and he eats an avocado

2.1 Determiner Mismatch in Peripheral Ellipsis

We argue that peripheral ellipsis may involve a determiner mismatch in French. Mouret & Abeillé (2011) provide an example with the negative polarity marker *de*:

(10) Il y a des langues qui ont ~~une flexion casuelle~~,
there are INDEF.PL languages REL.SBJ have ~~an inflection case~~
et des langues qui n' ont pas, de flexion casuelle.
and INDEF.PL languages REL.SBJ NEG have NEG, INDEF inflection case
'there are languages that have and languages that don't have case inflection.' (C. Hagège)

A *de* complement is not grammatical without the negation, and a determinerless complement is not either. (10) cannot be a case of complement drop since *avoir* does not allow for a null complement in French (Abeillé & Godard 2002).

Since no French corpora are annotated for ellipsis, we conducted a manual corpus study on the internet, with patterns involving coordination of clauses with frequent transitive verbs, with pronominal subjects, and a *de*-NP object. We found many similar examples on the Internet, some from carefully edited texts (11). They may involve a singular *un, une, du* or plural indefinite *des*.

(11) a. Les textes actuels permettent de citer à l'audience une personne, qu' elle ait ~~une dernière adresse connue~~
the texts current allow to cite in court a person COMP she has.SBJV ~~a last address known~~
ou qu' elle n' ait pas de dernière adresse connue.
or COMP she NEG has.SBJV NEG INDEF last address known
'The current texts allow one to cite in court a person, whether she has or she does not have any known adress.' (Avis Conseil d'Etat, July 2013)

b. Que la consommatrice cherche ou ne cherche pas un
COMP the consumer.F.SG look.for or NEG look.for not a
produit, qu' elle ait ~~du mal à le localiser~~
product, COMP she has.SBJV ~~INDEF.M.SG trouble to it locate~~
ou qu' elle n' ait pas de mal à le localiser,
or COMP she NEG has.SBJV NEG INDEF trouble to it locate,
il semble que son comportement [. . .]
it seems that her behaviour [. . .]

'Whether the consumer is or isn't looking for a product, whether she has or she doesn't have trouble locating it, it seems that her behaviour [. . .]' (Franck Cochoy, *Les figures sociales du client*, 2002)

c. C' est de la responsabilité de l' Eglise de venir en aide
It is of the responsability of the Church to come in help
aux migrants et aux réfugiés qu' ils
to.DET.PL migrants and to.DET.PL refugees COMP they
aient ~~des papiers~~ ou qu' ils n' aient
have.SBJV ~~INDEF.MPL papers~~ or COMP they NEG have.SBJV
pas de papiers.
NEG INDEF papers

'It is the Church's responsibility to help migrants and refugees whether they have or don't have papers.' (Mgr Dognin, Tours, 2014/08/01)

Such indefinites are analysed as markers in French (Dobrovie-Sorin & Beyssade 2004). When a more meaningful determiner is involved (12), such mismatches are more difficult.

(12) a. # Il y a des langues qui ont
there are INDEF.FPL languages REL.SBJ have
~~une flexion casuelle~~ et des langues qui n'
~~an inflection case~~ and INDEF.PL languages REL.SBJ NEG
ont aucune flexion casuelle
have any inflection case

'There are languages which have and languages which have no case inflection.'

b. qu'elle ait ~~deux adresses~~ ou qu'elle n'ait pas deux adresses …
'whether she has or she does not have two adresses …'
≠ qu'elle ait ~~une adresse~~ ou qu'elle n'ait pas deux adresses …

Further examples of mismatch involve bound determiners, in idiomatic expressions such as *ouvrir sa gueule* 'speak out' (lit: 'open one's mouth'):

(13) Je parle (…) de tous ceux qui se sont battus pour
I speak (…) of all those REL.SBJ REFL AUX.3PL fighted for
que je ~~puisse ouvrir ma gueule~~ et que tu puisses ouvrir
COMP I ~~can.SBJV open my mouth~~ and COMP you can.SBJV open
ta gueule en toute liberté
your mouth in all liberty
'I speak (…) of all those who have fought so that I and that you can speak out freely.' (`mouvement-ultra.forumactif.fr`, 2009)

2.2 Preposition Mismatch in Peripheral Ellipsis

As observed by Mouret & Abeillé (2011), some weak prepositions may also differ between the first and second conjunct. The preposition *à* is obligatory with *parvenir* 'manage', and *de* with *incapable* 'unable' (14). This cannot be a case of complement drop. The verb *parvenir* and the adjective *incapable* cannot appear without the complement even if the content of the complement is mentioned in the discourse.

(14) a. Ce parti ne parvient pas ~~à surmonter ses contradictions~~,
this party NEG manages NEG ~~to overcome its contradictions~~
voire ne souhaite pas, surmonter ses contradictions.
and.even NEG wishes NEG overcome its contradictions
'This party cannot manage, and may not even want to overcome its contradictions.' (Le Monde, French Treebank)

b. Une personne sur trois est incapable
one person on three is unable
~~de mener une vie indépendante~~ ou a beaucoup de mal
~~to lead a life independent~~ or has much of trouble

à mener une vie indépendante.
to lead a life independent

'One person out of three is unable or has trouble leading an independent life.' (France Inter, radio corpus Ester)

Since no French corpora are annotated for ellipsis, we conducted, again, a manual search on the internet, with patterns involving coordination of clauses with frequent verbs, taking *à* or *de* complements. We found many similar examples on the Internet, some from carefully edited texts. *À* and *de* are analyzed as infinitival markers (Abeillé et al. 2006). Mismatches with more meaningful prepositions would be more difficult:

(15) Qui est ~~pour démissionner~~ et qui n' est pas pour démissionner ?
who is ~~for resigning~~ and who NEG is NEG for resigning

'Who is and who is not in favour of resigning?'
≠ Qui est ~~contre démissionner~~ et qui n'est pas pour démissionner ?
'Who is against resigning and who is not for resigning?'

Although we did not conduct a systematic search, we also found some mismatches with a nominal complement (16a). As French prepositions *à/de* give rise to portmanteau forms *au/du*, some examples combine preposition and determiner mismatches (16b,c).

(16) a. un français qui va ~~à Hondarribia~~ ou qui revient d' Hondarribia ne verra que des panneaux et des cartes avec *Hondarribia*
a French-man REL.SBJ goes ~~to Hondarribia~~ or REL.SBJ returns from Hondarribia NEG see.FUT only INDEF.MPL signs and INDEF.FPL maps with Hondarribia

'A French man who goes or who comes from Hondarribia will only see signs and maps with *Hondarribia*.' (discussion, Wikipedia, 2007)

b. les brancardiers [...] avec toujours un sourire ou un
the stretcher bearers [...] with always a smile or a

mot rassurant pour un malade qui va
word reassuring for a patient REL.SBJ goes
~~au bloc~~ ou qui revient du bloc.
~~to.DET.M.SG room~~ or REL.SBJ returns FROM.DET.M.SG room

'the stretcher bearers [...] with always a smile or a reassuring word for a patient who is going or who is coming back from the operating room' (blog 2015)

c. même s' il rencontre ~~le pape François~~ ou s' il téléphone
even if he meets ~~the pope Francis~~ or if he calls
au pape François, il ne prend pas sa place.
to.DET.M.SG pope François, he NEG takes NEG his position

'even if he meets or if he calls Pope Francis, he doesn't take his position' (`lepeupledelapaix.forumactif.com`, 2015)

Similar examples can be found in English (Bilbîie 2013) (17a) and Spanish (Camacho 2003) (17c).

(17) a. They were also as liberal ~~as any other age group~~ or more liberal than any other age group in the 1986 through 1989 surveys. (Wall Street Journal, Penn Treebank)

b. They were also as liberal as/*than any other age group ...

c. Primero amedrentaron ~~a los manifestos~~ y luego
first harassed.3PL ~~to the demonstrators~~ and then
dispararon contra los manifestantes.
shot.3PL against the demonstrators

'First they harassed and then they shot at the demonstrators.'

d. Amedrentaron *(a) los manifestos.
harassed.3PL to DEF.M.PL demonstrators

'They harrassed the demonstrators.'

2.3 Experiment 1: Acceptability of Determiner and Preposition Mismatch

We performed experiments for determiner and preposition mismatches. The target items were inspired from attested examples with mismatches, and presented in three conditions:[1]

a. With ellipsis with determiner or preposition mismatch

(18) Il y a des gens qui ont, et des
there are INDEF.PL people REL.SBJ have and INDEF.PL
gens qui n' ont pas, de problème de poids.
people REL.SBJ NEG have NOT INDEF problem of weight
'There are people who have and people who don't have a weight problem.'

b. Without ellipsis nor mismatch (object clitic or pro-drop)

(19) Il y a des gens qui ont un problème de
there are INDEF.PL people REL.SBJ have a problem of
poids, et des gens qui n' en ont pas.
weight and INDEF.PL people REL.SBJ NEG of.it have NEG
'There are people who have a weight problem and people who don't have one.'

c. With ellipsis without mismatch

(20) Il y a des gens qui ont, et des
there are INDEF.PL people REL.SBJ have and INDEF.PL
gens qui n'ont pas, un problème de poids.
people REL.SBJ NEG have a problem of weight
'There are people who have and people who don't have a weight problem.'

We also included control items in three conditions:

a. Grammatical control

(21) Jean a le courage de ses opinions.
Jean has the courage of his opinions
'Jean stands up for what he believes.'

b. Ungrammatical control (zero determiner or preposition)

[1]The full set of experimental items is available at the site `http://www.llf.cnrs.fr/Ressources/`.

(22) * Jean a courage de ses opinions.
Jean has courage of his opinions
'Jean has courage of his opinions.'

c. Ungrammatical control (wrong determiner or preposition)

(23) * Jean a de courage de ses opinions
Jean has INDEF courage of his opinions
'Jean has any courage of his opinion.'

An acceptability judgement experiment with 24 items, 15 control and 24 fillers was programmed with Ibex platform (`http://spellout.net/ibexfarm/`). 41 native speakers who were recruited on the Risc website (`http://www.risc.cnrs.fr/`) judged the acceptability of the items on a 10 point scale.

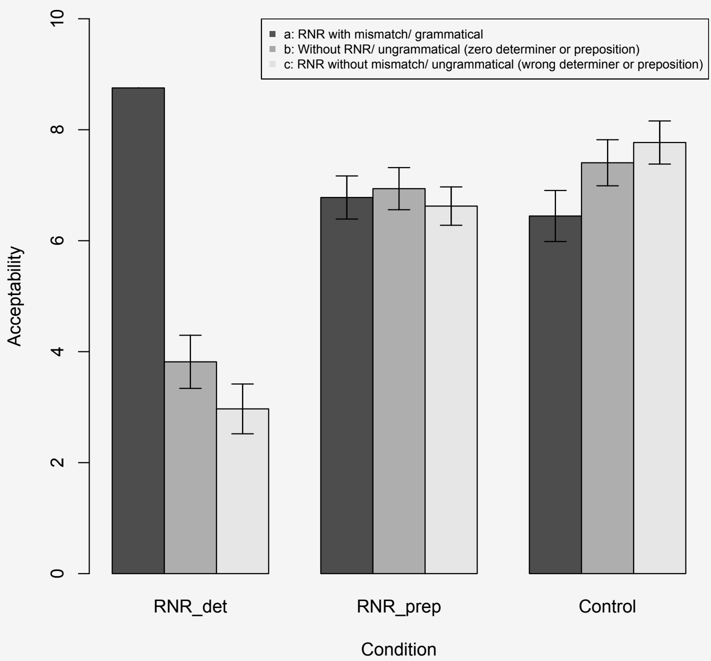

Figure 1 Determiner and Preposition Mismatch

As shown in figure 1, participants found no significant difference between peripheral ellipsis with a determiner mismatch (a: mean rate 6.779) and ellipsis without mismatch (c: mean rate 6.662). There was no significant difference between ellipsis with determiner mismatch (a) and coordination without ellipsis nor mismatch (b: mean rate 6.938). They found peripheral ellipsis with preposition mismatch (a: mean rate 6.445) less acceptable than ellipsis without mismatch (c: mean rate 7.77), but much higher than ungrammatical controls (mean rate 3.392). There was no significant difference between ellipsis without preposition mismatch (a) and coordination without ellipsis nor mismatch (b: mean rate 7.404). These results suggest that determiner and preposition mismatches in peripheral ellipsis are not a simple production error.

Such determiner and preposition mismatches are difficult to analyze in raising or multiple dominance approaches, since the shared element always meets the requirement of the second conjunct: it appears to fully belong to the second conjunct, and would be ungrammatical, if reconstructed verbatim into the first one.

3 Voice Mismatch in Peripheral Ellipsis

3.1 Searching for Voice Mismatch in French Peripheral Ellipsis

In French, as in English, past and passive participles are syncretic forms. However, it is not so easy to have a shared participle in final position. The same entity has to serve as the first argument (in the active) and as the second argument (in the passive), so the verb must be reversible. If we test active verbs with an NP complement and passives with a *by*-phrase, the result is a discontinuous ellipsis, which is not very natural:

(24) Le ballon aura ~~touché l'un des joueurs sur le terrain~~ ou
the ball have.FUT ~~touched one of.the players on the field~~ or
aura été touché par l'un des joueurs sur le terrain.
have.FUT been touched by one of.DET.M.PL players on the field

'The ball will have or will have been touched by one of the players on the field.' (basketsarthe.dyndns.org, 2009)

The shared elements are the participle *touché* 'touched' and the NP *l'un des joueurs sur le terrain* 'one of the players on the field', but not the preposition *par* 'by'. If we test reversible transitive verbs (*convaincre* 'convince', *comprendre* 'understand') without a complement in the active voice (pro-dropped object; 25a), and with a short passive, peripheral ellipsis is not very natural either (25b,c).

(25) a. Qui a compris / convaincu?
who has understood / convinced?
'Who has understood/managed to convince?'

b. ? C'est ainsi qu' ont parlé ceux qui ont été ~~compris~~ et ceux qui ont compris.
this is how that have spoken those who have been ~~understood~~ and those who have understood
'that is how those who have been understood and those who have understood spoke.'

c. ? Paul a été ~~convaincu~~, mais son frère a convaincu.
Paul has been ~~convinced~~ but his brother has convinced
'Paul has been but his brother has managed to convince.'

Examples (25b,c) involve contrastive topics, which disallow voice mismatch in English VP ellipsis (Kertz 2013). Moreover, they do not keep the same participants: the first argument is unspecified in the short passive, whereas it is the second argument (pro-dropped object) which is unspecified in the active voice. In order to keep at least one participant constant, we conducted a manual search on the web, for coordination of relative clauses with active and passive auxiliaries.

In our search patterns, we took advantage of the fact that the active relative clauses were introduced by *que* with a gap object and an indefinite subject *on* 'one' and the passive ones were introduced by *qui* (with a gap subject), so the patient is the same in both active and passive sentences. We found a few such examples in well-written prose (26a) or as dictionary definitions (26b).

(26) a. … donner la parole à ceux qu' on a
… give the voice to those REL one has
~~privés de dire~~ ou qui sont privés de dire.
~~deprived of saying~~ or who are deprived of saying
'… let those speak that one has or who are deprived of talking' (`www.cemea.asso.fr`, 1997) [Fernand Deligny]

b. Épousée, s, /. celle qu' on a ~~épousée~~ ou qui
spouse.F, s, /. that.F.SG REL.OBJ one has ~~married~~ or REL.SBJ
doit être bientôt épousée.
must be soon married
'Spouse, -s. A woman who someone has taken as his spouse and who is soon to be taken as a spouse' (*Dictionnaire universel de la langue françoise*, PCV Boiste 1803)

In these examples, there is a semantic contrast between the two conjuncts: in tense (past active/present passive) in (26a), in tense and modality in (26b): past active/deontic and future passive.

We have also looked for reflexive actives, and the results were much more numerous, both active-passive (27a) and passive-active (27b):

(27) a. Ce pharmacien doit des explications à ceux
This pharmacist owes INDEF.F.PL explanations to those
qui se sont ~~mobilisés pour lui~~ ou qui ont été
REL.SBJ REFL AUX ~~mobilized for him~~ or REL.SBJ have been
mobilisés pour lui.
mobilized for him
'This pharmacist owes explanations to those who tallied to his cause, or who were rallied to it.' (`www.ipreunion.com`, 2013)

b. il y a aussi, tous ceux qui ont été ~~exclus~~ ou
there are also all those REL.SBJ have been ~~excluded~~ or
qui se sont exclus […]
REL.SBJ REFL AUX excluded
'there are also all those who were excluded or who excluded themselves …' (`www.ville-yzeure.com`, 2008)

It is worth noting that these examples cannot be analysed as cataphoric VP ellipsis. Cataphoric VP ellipsis is supposed to involve subordination (28a). Furthermore, French auxiliaries do not allow for VP ellipsis (28b,c) (Abeillé & Godard 1994).[2]

(28) a. If you can, you should leave now.

b. * Jean a démissionné mais Marie n' a pas.
Jean has resigned but Marie NEG has NEG
'Jean has resigned but Marie has not.'

c. * Certains ont été exclus mais d' autres n' ont pas été.
certain have been excluded but INDEF.PL others NEG have NEG been
'Some have been excluded but some others have not been.'

3.2 Semantic Contrast in Peripheral Ellipsis

Peripheral ellipsis requires a semantic contrast between the two conjuncts. For English, Huddleston & Pullum (2002) observe that subject contrast is not sufficient and verb contrast is needed too (29).

(29) Bill likes, and Mary hates/#likes, the TV show. (Ha 2008)

Bilbîie (2013) conducted a systematic study of the Penn Treebank, which is annotated for ellipsis. She found that RNR is quite rare with different subjects (30a) and tends to involve S coordination with the same subject (30c,d) and more often VP coordination (30b). Usually English RNR involves a tense (30b), polarity (30c), or modality (30d) contrast.

(30) a. The police said, all the people said, that's fine. (swbd-104656)

[2] In German too, voice mismatch appears to be grammatical with peripheral ellipsis:

i. Einige haben sich gleich freiwillig, die restlichen wurden dann zwangsweise geopfert.
some have SELF immediately voluntarily, the rest were then by force sacrified
'Some (sacrificed) themselves voluntarily straight away, the others were later sacrificed by force.'

b. But the South is, and has been for the past century, engaged in a wide-sweeping urbanization … (brwn-16897)

c. Did you or did you not say what I said you said …? (brwn-4498)

d. Who is and who should be making the criminal law here? (wsj-6370)

Similar results were found by Mouret & Abeillé (2011) in French written (French treebank) and spoken corpora (Ester), although their study was not systematic (the corpora are not annotated for ellipsis). In (31a), the two conjuncts contrast in modality and in (31b) in tense.

(31) a. il ne pouvait ~~rien lui refuser~~, il ne voulait rien lui refuser
he NEG could ~~nothing to.her refuse~~, he NEG wanted nothing to.her refuse
'he couldn't refuse her anything, nor did he want to' (Ester corpus, April 2003, France Info)

b. demain nous verrons si les socialistes se sont remis ~~de leur débâcle du 21 avril 2002~~ ou se remettent de leur débâcle du 21 avril 2002
tomorrow we see.FUT whether the socialists REFL AUX recovered ~~from their defeat of 21 april 2002~~ or REFL recover from their defeat of 21 april 2002
'tomorrow, we'll see whether the socialists have recovered or are recovering from their 21st April 2002 defeat' (Ester corpus, April 2003, France Inter)

3.3 Experiment 2: Testing for Voice Mismatch and Semantic Contrast in French Peripheral Ellipsis

In order to test the acceptability of the examples with voice mismatch that we found on the internet, we conducted an acceptability judgement task, with 12 target items and 56 distractors. 62 native speakers who were recruited on the Risc website (`http://www.risc.cnrs.fr/`) judged the acceptability of the items on a 10-point scale.

The target items were inspired from attested examples with mismatches, and presented in four variants:

a. With role contrast, with voice mismatch (active-passive)

(32) Il s'agit d' Eglises orientales qui se sont, ou
these are of Churches eastern REL.SBJ REFL are or
qui ont été rattachées à Rome.
REL.SBJ have been attached to Rome
'These are Eastern Churches that joined Rome or that were joined to it.'

b. Without role contrast, with voice mismatch (active-passive)

(33) Il s'agit d' Eglises orientales qu' on a, ou
these are of Churches eastern REL.OBJ one has or
qui ont été rattachées à Rome.
REL.SBJ have been attached to Rome
'These are Eastern churches that one has joined to Rome or that have been joined to it.'

c. With role contrast, without mismatch (active-active)

(34) Il s'agit d' Eglises orientales qui se sont, ou
these are of Churches eastern REL.SBJ REFL are or
qu' on a rattachées à Rome.
REL.OBJ one has attached to Rome
'These are Eastern churches that joined Rome, or that one joined to Rome.'

d. Without role contrast, without mismatch (passive-passive)

(35) Il s'agit d' Eglises orientales qui étaient, ou
these are of Churches eastern REL.SBJ were or
qui ont été rattachées à Rome.
REL.SBJ have been attached to Rome
'These are Eastern churches that were or that have been joined to Rome.'

There is a contrast in semantic role in (a) and (c): with a reflexive active, the agent is specified and is different from the agentless passive or from the active with an indefinite subject (*on*). On the other hand, when the active has an indefinite subject (*on*) there is no role contrast with the agentless passive (b). In the last case (d: two passives), there is no role contrast, and a minimal tense contrast (the imparfait *étaient* 'were' has a very weak contrast with the passé composé *ont été* 'have been').

The results are presented in figure 2. The items with semantic contrast and voice mismatch were rated slightly lower (a: mean rate 8.145) than those with contrast without mismatch (c: mean rate 8.217) but slightly higher than those without contrast and without mismatch (b: mean rate 8.036) and higher than those without contrast with mismatch (d: mean rate 7.667).

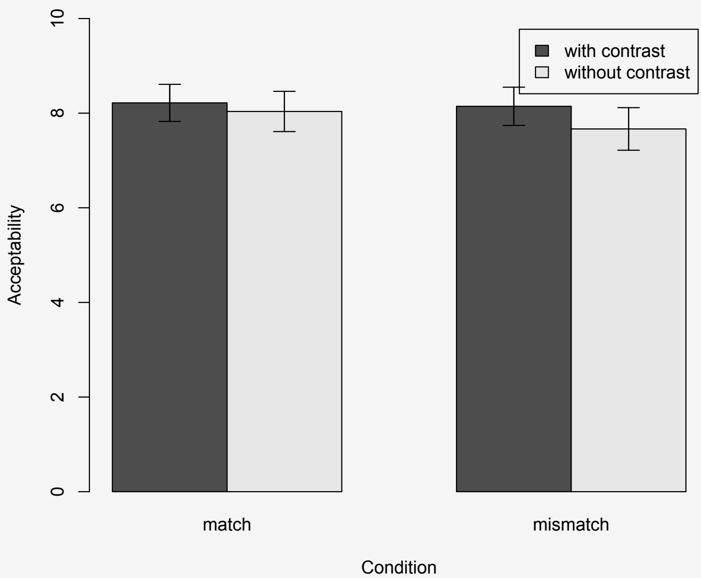

Figure 2 Voice Mismatch

We ran a mixed-effect linear regression model; there was no significant effect with match and contrast interaction. When we ran a model without interaction, there was no significant effect of voice match (p=0.6649) but a significant effect of contrast (p=0.0495). Only the semantic condition of contrast played a role: there was no significant effect of voice match (the syntactic condition). The items with voice mismatch and role contrast were not less acceptable than the ones with voice match and no contrast.

4 An Analysis in Head-driven Phrase Structure Grammar (HPSG)

The mismatch data pertaining to peripheral ellipsis in French that we have presented in this paper provide an immediate challenge for any approach to the phenomenon that relies on *syntactic* identity of shared material, including multidominance, syntactic raising or extraction, or deletion under *syntactic* identity. The most striking case is presented by preposition mismatch, as this information cannot be easily made compatible across the two sites, since the differences must be syntactically present in order for preposition selection to work correctly when used outside this construction. We therefore argue that the data investigated here call for a revised notion of deletion under identity which cannot be syntactic in nature, but will rely instead on notions of phonological and semantic identity.

In the analysis we are going to pursue here, we shall build on previous surface-oriented approaches to non-classical coordination, as developed by Yatabe (2001, 2003), Crysmann (2003a), Chaves (2008, 2014) in the framework of HPSG.

The first major challenge the French data confront us with is how to reconcile obvious mismatch in surface form with the syncretism requirement identified by Pullum & Zwicky (1986). Given the examples in (8), we want to insist on strict phonological identity, whereas French determiner or preposition mismatch show that the phonological identity requirement must be relaxed. The second important aspect to be captured is the contrast between phonological identity and semantic, or lexemic, identity and zeugma, that is, accidental phonological identity, as witnessed by homophones, as in (9c,d). This connects to a more general requirement on theories of ellipsis, namely, the broader question of semantic recoverability.

The key to our analysis is to combine these requirements, and capitalise on the semantic difference between surface forms that allow mismatch, compared to those that do not: while permissible mismatch involves what can broadly be characterised as functional elements, strict identity appears to be required by semantically contentful material, both on the phonological and the semantic side. Essentially, we propose that functional prepositions are semantically empty, yet syntactically selected for, which will account for their (syntactic) recoverability. Similarly, we observed that bound possessives and indefinite determiners (see (11) and (13)) contrast with true generalised quantifiers (see (12)) (Heim 1982, Dobrovie-Sorin & Beyssade 2004). Building on a previous proposal by Abeillé et al. (2006), who analyse French indefinite determiners as number markers lacking a semantic predicate, we shall assume that definite and indefinite articles are not semantically potent by themselves, but instead are markers that syntactically signal a property of the noun they specify. If this analysis is on the right track, we can characterise the conditions under which mismatch can arise as involving semantically vacuous elements only.[3]

To summarise the empirical generalisation underlying our analysis, we assume that (i) content-full peripheral material has to be shared on the right; (ii) content-less material can be asymmetrically elided on the left. The case of mismatch with content-less material can be sketched informally as follows (from (11a) and (14a)):

Determiner: <qu'elle ait> ~~<une><adresse connue>~~
<ou qu'elle n'ait pas> <**d'**><adresse connue>
Preposition: <ne parvient pas> ~~<à> <surmonter ses contradictions>~~
<voire ne souhaite pas> <surmonter ses contradictions>

Having outlined the basic intuitions, we are now in a position to turn to the formal analysis. As a first step towards a surface-deletion account, we need to be able to distinguish between phonological representations that are semantically grounded (exponents of semantic predicates), and those that are not (purely functional elements). In order to do this in a principled fashion, we shall postulate that members of the PHON list are structured, consisting at least of a feature SEG, which carries the segmental information proper, and LNK, which establishes a pointer to the semantic predicates it contributes to. Since bits of phonology may correspond to more than one predicate, or none, in the case of functional elements, the

[3] If definiteness is a property associated with the head noun's semantic variable, recoverability is ensured by sharing of the noun's predicate.

value of LNK is a (possibly empty) list. We shall use Minimal Recursion Semantics (MRS; Copestake et al. 2005) as our semantic description language.

Example (36) illustrates semantic grounding of the phonology of the quantifier *aucune*, which is expressed by having the element(s) on LNK of every segment be reentrant with the lexical predicate. In general, the LNK list for every segment of a lexical (or sub-lexical) item is exactly the concatenation of the PRED values on that items list of elementary predications RELS:

(36) Lexical representation of content-full quantifier *aucune* 'no'

$$\begin{bmatrix} \text{PHON} & \left\langle \begin{bmatrix}\text{SEG o}\\ \text{LNK}\left\langle \boxed{p} \right\rangle\end{bmatrix}, \begin{bmatrix}\text{SEG k}\\ \text{LNK}\left\langle \boxed{p} \right\rangle\end{bmatrix}, \begin{bmatrix}\text{SEG y}\\ \text{LNK}\left\langle \boxed{p} \right\rangle\end{bmatrix}, \begin{bmatrix}\text{SEG n}\\ \text{LNK}\left\langle \boxed{p} \right\rangle\end{bmatrix} \right\rangle \\ \text{CONT} & \begin{bmatrix} \text{INDEX} & \boxed{i}\begin{bmatrix}\text{NUM} & sg\\ \text{GEND} & f\end{bmatrix} \\ \text{RELS} & \left\langle \begin{bmatrix} \text{PRED} & \boxed{p}\ \textit{"\_aucun\_q\_rel"} \\ \text{ARG0} & \boxed{i} \\ \text{RSTR} & \textit{handle} \\ \text{BODY} & \textit{handle} \end{bmatrix} \right\rangle \end{bmatrix} \end{bmatrix}$$

Functional elements, like the indefinite number marker UNE, by contrast, are characterised by having the empty list as the value of LNK, by virtue of the fact that the RELS list is empty and therefore does not have any elements with a PRED value, as in (37).

(37) Lexical representation of functional indefinite *une* 'a(n)'

$$\begin{bmatrix} \text{PHON} & \left\langle \begin{bmatrix}\text{SEG} & \text{y}\\ \text{LNK} & \langle\, \rangle\end{bmatrix}, \begin{bmatrix}\text{SEG} & \text{n}\\ \text{LNK} & \langle\, \rangle\end{bmatrix} \right\rangle \\ \text{CONT} & \begin{bmatrix} \text{INDEX} & \begin{bmatrix}\text{NUM} & sg\\ \text{GEND} & f\end{bmatrix} \\ \text{RELS} & \langle\, \rangle \end{bmatrix} \end{bmatrix}$$

With this representation in place, we are now in a position to provide an initial account of peripheral sharing by means of the RNR unary phrase structure rule:

(38) RNR unary rule (preliminary version)

rnr-unary-phr →

$$\begin{bmatrix} \text{PHON} & \boxed{l_1} \oplus \boxed{r_1} \oplus \boxed{r_2} \oplus \boxed{lr} \\ \text{SYNSEM} & \boxed{s} \\ \text{DTRS} & \left\langle \begin{bmatrix} \text{PHON} & \boxed{l_1} \oplus \boxed{l_2}\ \mathit{list}\left(\begin{bmatrix}\text{LNK}\ \langle\rangle\end{bmatrix}\right) \oplus \boxed{lr} \oplus \boxed{r_1} \oplus \boxed{r_2}\ \mathit{list}\left(\begin{bmatrix}\text{LNK}\ \langle\rangle\end{bmatrix}\right) \oplus \boxed{lr} \\ \text{SYNSEM} & \boxed{s} \end{bmatrix} \right\rangle \end{bmatrix}$$

As detailed by the rule definition in (38), peripheral sharing is treated as sharing of peripheral phonology $\boxed{lr}$, combined with asymmetric suppression of semantically vacuous phonological material adjacent to the left of the shared phonology. That is to say, the rule partitions the phonological list of the (single) daughter[4] into a left initial substring $\boxed{l_1}$, a left stretch of semantically vacuous segments $\boxed{l_2}$, and the left-hand part of the shared peripheral stretch $\boxed{lr}$. Similarly, it parses the remainder of the list into an initial right stretch $\boxed{r_1}$, a stretch of semantically vacuous segments ($\boxed{r_2}$), and finally the right counterpart of the shared right-peripheral stretch $\boxed{lr}$. Basic peripheral sharing is then induced by way of collapsing the two identical stretches $\boxed{lr}$ on the daughter in right-peripheral surface position on the mother. This analysis is essentially very close to previous analyses developed by Yatabe (2001, 2003), Crysmann (2003a), Chaves (2008), albeit recast to apply at a phonological level, rather than domain objects. Where our approach differs is in the treatment of mismatch: while the semantically vacuous stretch adjacent to the right-most shared stretch ($\boxed{r_2}$) must be preserved on the mother, the non-adjacent $\boxed{l_2}$ may be asymmetrically suppressed.

The partitioning of phonological strings into sub-strings by way of the RNR rule is illustrated in figure 3: it shows on the basis of RNR with determiner mismatch how the phonological sub-strings are instantiated to

[4] Since peripheral sharing cannot be restricted to any particular syntactic construction, like (e.g.) coordination, we picture it as a phonological edit conditioned on the presence of identical phonological material. Furthermore, since it is a phrase structure rule, it may apply recursively, that is, the analysis is not restricted to binary sharing.

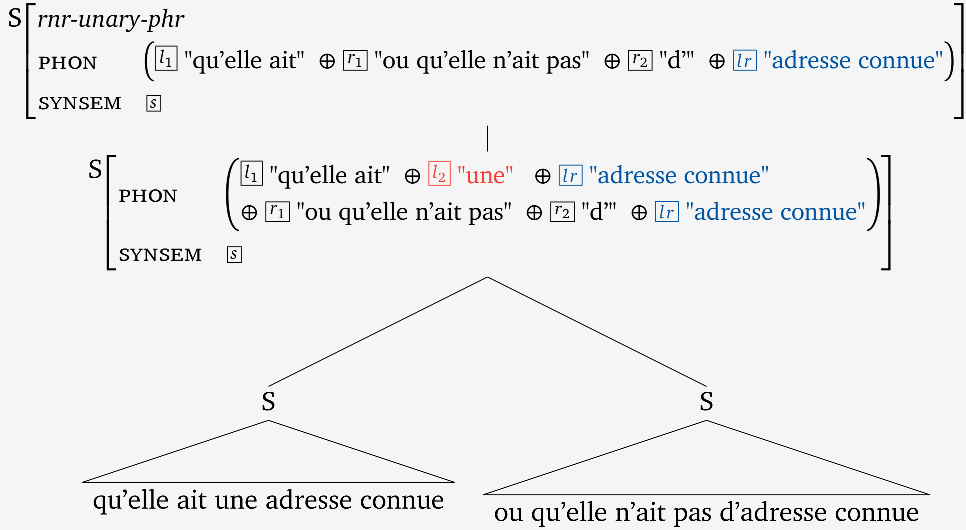

Figure 3 Analysis of *qu'elle ait …*

non-shared initial stretches ($\boxed{l_1}$ and $\boxed{r_1}$), a shared right-peripheral stretch $\boxed{lr}$, and medial sub-strings, which are required to be semantically empty, thus permitting asymmetric elision on the left ($\boxed{l_2}$). For ease of exposition, we are using orthographic strings here, rather than lists of feature structures describing phonological events.

The basic analysis as developed so far already has some desirable properties: since phonology is semantically grounded, that is, the LNK feature records for every piece of phonology which predicates (if any) license it, we can straightforwardly implement a distinction between contentful and contentless phonology, thereby enabling us to selectively permit asymmetric elision of the phonology of functional elements. Furthermore, thanks to semantic grounding, sharing of phonology entails sharing of the corresponding semantic predicates. Thus zeugma will be detected as an attempt to unify distinct semantic predicates.

Finally, the surface-phonological approach also provides a direct answer for voice mismatch (from (27)):

(39) <qui se sont> ~~<mobilisés pour lui>~~
<ou qui ont été> <mobilisés pour lui>

Verbatim sharing of participle phonology captures the syncretism requirement, since the rightmost passive or perfect participle is always a lexical verb, and therefore carries a semantic predicate. Syntactic properties, for example, pertaining to valency, by contrast are systematically ignored under our approach, so that conflict with respect to these properties simply cannot arise, since identity requirements are stated exclusively in terms of (semantically grounded) phonology.

Before we close, however, we shall briefly address one more central property of peripheral sharing, namely, prosodic conditioning. It has been repeatedly noted in the literature that peripheral sharing in general, and sublexical sharing in particular, are subject to phonological minimality conditions (Hartmann 2000, Chaves 2014). French peripheral sharing seems to confirm this: as we have observed above, asymmetric deletion of function words is the only way to resolve mismatch in peripheral sharing constructions. Since these function words are prosodically weak (Miller 1992), the impossibility of stranding French function words on the left ((40); from (10) and (14)) falls out, once we incorporate prosodic conditions on well-formedness.

(40) a. * Il y a des langues qui ont une
there are INDEF.PL languages REL.SBJ have an
~~flexion casuelle~~, et des langues qui n'
~~inflection case~~ and INDEF.PL languages REL.SBJ NEG
ont pas, de flexion casuelle.
have NEG, INDEF inflection case

b. * Ce parti ne parvient pas à
This party NEG manages NEG to
~~surmonter ses contradictions~~, voire ne souhaite pas,
~~overcome its contradictions~~ and.even NEG wishes NEG
surmonter ses contradictions.
overcome its contradictions

Informally,[5] this can be achieved by requiring the phonological sub-lists on the mother of (38), namely, $\boxed{l_1}$, $\boxed{r_1}$, $\boxed{r_2}$, and $\boxed{lr}$ to all coincide with prosodic word boundaries. Once this constraint is imposed, it is clear that, for ex-

[5]The current proposal can be made fully explicit using (e.g.) the segment-based encoding of the Prosodic Hierachy (Selkirk 1986) proposed in Crysmann (2003b:chap. 6).

ample, the non-shared left stretch $\boxed{l_1}$ cannot terminate in a weak function word, which is characterised by not having a right prosodic word boundary. As a result, such a function word can only be retained, if its host is in an adjacent surface position, leaving suppression on the left as the only option, since adjacency breaks under peripheral sharing.

The fundamental intuition behind our analysis is that mismatch in sharing is resolved in favour of keeping the contiguous right stretch intact. By resolving mismatch at the expense of asymmetric suppression of conflicting semantically empty material from the left, we can at the same time account for syncretism effects, detect zeugma, and more generally ensure semantic recoverability. However, the exact formulation, while true to the evidence presented so far, has been simplified for expository purposes. In order to capture the full range of patterns in peripheral sharing, we need to cater for two other cases of asymmetry: first, we observe that mismatch on the left is not necessarily restricted to be left-adjacent to the shared peripheral material, but may just as well be interleaved with the shared right-peripheral material, as illustrated in (41).

(41) qu' ils aient ~~fait~~ ~~des~~ ~~progrès~~ ou qu' ils
COMP they have.SBJV made INDEF.PL progress or COMP they
n' aient pas fait de progrès
NEG have.SBJV NEG made INDEF progress
'Whether they have made any progress or not'

As seen in this example, mismatch between the polarity variants *des* and *de* is contained within the peripherally shared stretch featuring the semantically potent *fait* and *progrès*. Mismatch resolution, however, is still in line with our baseline analysis, giving preference to preservation of material from the contiguous right-hand stretch.

The second refinement that is in order concerns what has been called medial RNR or wrapping. Apparently, the peripherality requirement can be relaxed, again favouring the contiguous stretch on the right: that is, material following the shared "peripheral" stretch can be projected asymmetrically from the right.

(42) des églises qui se sont ~~rattachées à Rome~~ ou qui
churches REL.SUBJ SELF are attached to Rome or REL.SUBJ
ont été rattachées à Rome par la force
have been attached to Rome by the force
'churches which have or have have been attached to Rome by force'

As exemplified by (42), the final PP *par la force* cannot felicitously be construed with the reflexive *se sont ~~rattachés à Rome~~* on the left, but can only be associated with the passive *ont été rattachés à Rome* on the right. As a result, the shared peripheral material is not found in absolute right-peripheral position. Yet, despite this complication, wrapping still falls in with our observation that verbatim preservation of material on the right is privileged by peripheral sharing constructions.

We therefore propose the following revised version of the unary RNR construction.

(43) RNR unary rule (final version)

$$\textit{rnr-unary-phr} \rightarrow \begin{bmatrix} \text{PHON} & \boxed{l_1} \oplus \boxed{r_1} \oplus \boxed{r_2} \oplus \boxed{r_3} \\ \text{SYNSEM} & \boxed{s} \\ \text{DTRS} & \left\langle \begin{bmatrix} \text{PHON} & \boxed{l_1} \oplus \boxed{l_2} \left(\begin{array}{l} \boxed{lr_1} \\ \oplus \\ \textit{list}\left(\left[\text{LNK}\ \langle\rangle\right]\right) \\ \oplus \\ \boxed{lr_2} \end{array}\right) \oplus \boxed{r_1} \oplus \boxed{r_2} \left(\begin{array}{l} \boxed{lr_1} \\ \oplus \\ \textit{list}\left(\left[\text{LNK}\ \langle\rangle\right]\right) \\ \oplus \\ \boxed{lr_2} \end{array}\right) \oplus \boxed{r_3} \\ \text{SYNSEM} & \boxed{s} \end{bmatrix} \right\rangle \end{bmatrix}$$

where $\boxed{l_1} = <[], \ldots> \wedge \boxed{r_1} = <[], \ldots> \wedge \boxed{lr_2} = <[], \ldots>$

As depicted by the rule in (43), the right-hand phonology is parsed into three partitions, each of which is projected onto the mother. This straightforwardly captures our observation made above that the right stretch is always preserved continuously. Congruent with our previous formalisation, the non-shared initial left stretch ($\boxed{l_1}$) is projected to the mother. The first deviation from the baseline formalisation in (38) relates to the mismatch exemplified in (41): instead of insisting that the semantically empty mismatching material (LNK < >) precede the shared material ($\boxed{lr}$), we parse the relevant stretch $\boxed{r_2}$ into a possibly empty shared initial stretch $\boxed{lr_1}$, a semantically empty stretch, which is asymmetrically projected from the right, and a non-empty final shared stretch $\boxed{lr_2}$.

The second deviation from the baseline analysis concerns wrapping: unlike (38), our refined version caters for the possibility that the "peripheral" shared stretch (containing $\boxed{lr_1}$ and $\boxed{lr_2}$) need not be peripheral on the right, allowing for the possibility to project asymmetrically from the right, which will take care of wrapping or medial RNR.

To summarise, our revised analysis of French peripheral sharing integrates both medial RNR and non-peripheral asymmetric ellipsis on the left, while keeping with the fundamental intuition that peripheral sharing keeps the right stretch intact. Furthermore, sharing and asymmetric suppression on the left is constrained by strict phonological identity of semantically grounded material, simultaneously providing an account of zeugma and the syncretism requirement.

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Discourse Particle *denn* in the Antecedent of Conditionals

Eva Csipak • Sarah Zobel

Abstract In this paper, we discuss the semantic contribution and discourse effect of "conditional *denn*," the occurrence of the German discourse particle *denn* in the antecedent of a conditional. We show that its presence signals that the speaker calls into question the validity of the antecedent proposition. For the use of conditional *denn* to be acceptable, this proposition must have been in the set of public commitments of a discourse participant as well as be in a particular relation with a previously uttered proposition.

Keywords discourse particle · German · *denn* · conditionals · pragmatics

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In Christopher Piñón (ed.), Empirical Issues in Syntax and Semantics 11, 31–60. Paris: CSSP.
http://www.cssp.cnrs.fr/eiss11/

1 Introduction

The German word *denn* has many uses—for example, as a causal conjunction, as in (1a), as an archaic comparative particle, as in (1b), and as a discourse particle.[1] In its discourse particle use, it is most frequently found in questions, as seen in (1c). And indeed the literature on discourse particle *denn* almost exclusively discusses its use in questions (e.g., Thurmair 1989, 1991, Bayer 2012, but see Brauße 1994, Kwon 2005, Coniglio 2011, Häussler 2015).

(1) a. Maria ist froh, **denn** Peter kommt zur Party.
Maria is happy because Peter comes to.the party
'Maria is happy because Peter is coming to the party.'

b. Maria mag Peter mehr **denn** je.
Maria likes Peter more than ever

[1] Note that we only investigate the unstressed variant of discourse particle *denn*. Stressed *denn* cannot occur in the antecedents of conditionals, only in questions.

c. Mag Peter **denn** Maria?
likes Peter DENN Maria
'Does Peter DENN like Maria?'

The present paper focuses on the use of discourse particle *denn* in the antecedent of a conditional (henceforth: conditional *denn*), as in (2).[2]

(2) Sein Auto habe ich nicht gesehen, wenn er **denn** eines hat.
His car have I not seen if he DENN one has
'I didn't see his car if he DENN owns one.'

We observe that conditional *denn* serves a particular function: it emphasizes the fact that the speaker is not committed to the truth of the antecedent proposition, while also signaling that accepting a previous discourse move requires accepting the antecedent proposition. Note that the source of this previous discourse move may be a timeslice of the speaker herself, as is the case in (2). By introducing the discourse referent *his car* in the consequent, the speaker presupposes that "he" owns a car. The antecedent containing *denn* emphasizes that this presupposition is not intended.

In this paper, we propose a semantics for conditional *denn*. We also discuss its distribution and properties and suggest why a unified analysis of conditional *denn* and question *denn* is not feasible. Furthermore, we address how antecedents containing *denn* differ from other expressions with a similar function. The rest of the paper is structured as follows. In section 2, we present the relevant data needed to give a better overview over the distribution of conditional *denn*. Section 3 discusses existing formal proposals for discourse particle *denn* and shows how conditional *denn* differs from question *denn*. Section 4 contains our proposal for conditional *denn* spelled out in the discourse model proposed in Farkas & Bruce 2010. In section 5, we compare antecedents containing *denn* to antecedents con-

[2]To get a picture of the relative frequency of the two uses, we utilized the corpus of Spoken German ("Gesprochene Sprache," ≈ 2.5 million tokens), which is part of the DWDS online platform (`http://dwds.de/`): compared to *denn* in questions, conditional *denn* is rare making up just about 3–5% of all particle uses. This estimate is based on a random sample of 200 tokens of *denn* (exported: 2016/01/30). For reasons of space, the details of this study cannot be presented here.

taining *überhaupt*, another German discourse particle with a similar function. Section 6 concludes.

Note that stressing the subordinator *wenn* of an antecedent seems to have its own pragmatic effect. Because pragmatic effects based on prosody are beyond the scope of this paper, all judgments regarding the (un)acceptability of conditional *denn* are made for antecedents with unstressed *wenn*. We leave the—undoubtedly necessary—work on the interaction of the contribution of conditional *denn* with prosody and information structure for future work.

2 Data

2.1 Conditional *denn* and Types of Conditionals

Semantically, there are different varieties of conditionals—for instance, hypothetical indicative and subjunctive, temporal, factual, and biscuit conditionals.[3] Conditional *denn* can only occur in some of these varieties. As we stated in the introduction, conditional *denn* at once emphasizes that the speaker is not committed to the proposition p expressed by the antecedent it occurs in as well as signaling that accepting p is a prerequisite for accepting a previous discourse move. Thus the speaker does not believe p to hold in the actual world w_0. This characterization immediately restricts the use of conditional *denn* and excludes it from occurring in the antecedents of factual or temporal conditionals.[4]

For reasons of space, most observations in this and the following subsection are illustrated only by *protest cases* in dialogue form as in (3), but all observations also hold for *self-qualification cases* like (2).

The incompatibility of conditional *denn* with factual conditionals is illustrated in the following example:[5]

[3]German *wenn* is an all-purpose conditional subordinator. It can introduce the antecedent of any of these varieties (see Fabricius-Hansen & Sæbø 1983, Breindl et al. 2014), as well as other types of conditionals not mentioned here.

[4]Importantly, we do not claim that the proposition p expressed by the antecedent of a temporal conditional holds in w_0. We claim that if a speaker uses a temporal conditional, she believes that p will hold at some point in w_0 (see Fabricius-Hansen & Sæbø 1983).

[5]For reasons of space, whenever we provide contextual clues such as an utterance preceding the target utterance containing *denn*, we will give them in English only.

(3) A: Look, it is sunny!
B: Stimmt! Wenn es (#denn) sonnig ist, können wir spazieren
true if it DENN sunny is can we walk
gehen.
go
'Right! If it is (#DENN) sunny, we can go for a walk.'

Since A's utterance and B's uptake jointly establish the interlocutors' belief that it is sunny in w_0, B's utterance can only reasonably be interpreted as a factual conditional, that is, B's antecedent takes up the proposition expressed by A's utterance and presents a possibility that arises from establishing that this proposition holds in w_0. As expected, conditional *denn* is unacceptable.

Out of the blue, conditionals formed with the all-purpose subordinator *wenn* are ambiguous between a hypothetical interpretation and a purely temporal one, as shown in (4).

(4) a. Wir gehen schwimmen, wenn Peter kommt.
b. 'We will go swimming if Peter arrives.'
Hypothetical conditional
c. 'We will go swimming when Peter arrives.'
Temporal conditional

Inserting *denn* into the antecedent of (4a) disambiguates the meaning of the conditional in favour of the hypothetical conditional reading in (4b). This means that if the context disambiguates the interpretation towards the temporal reading, conditional *denn* is expected to be unacceptable, as seen in (5).

(5) A: I just checked my mail. Peter will arrive between 2 p.m. and 4 p.m.
B: Gut, und wenn Peter (#denn) kommt, können wir
good and if Peter DENN comes can we
schwimmen gehen.
swimming go
'Good, and when Peter (#DENN) comes, we can go swimming.'

A's utterance and B's uptake establish that Peter will arrive some time later today, which disambiguates B's utterance towards a temporal interpretation. B's utterance without *denn* is perfectly acceptable in this interpretation: it is not known exactly when Peter will arrive, but when he does, the group can go swimming. However, with *denn* the utterance can only be interpreted as a hypothetical conditional, which clashes with the given context.

Other types of conditionals are compatible with conditional *denn* as long as the speaker is not committed to the truth of the proposition expressed by their antecedents. Hence, biscuit conditionals and subjunctive conditionals can host conditional *denn*, as in (6) and (7), respectively. For reasons of space, we will only focus on indicative hypothetical conditionals here.

(6) Da drüben sind Kekse, wenn du denn welche willst.
there there are cookies if you DENN some want
'Over there are biscuits if you DENN want some.'

(7) Der Film würde Alex gefallen, wenn er denn käme.
the movie would Alex please if he DENN come.SUBJ
'Alex would like the movie if he DENN came.'

The upshot of this section is that conditional *denn* is only acceptable if the speaker is not committed to the truth of the antecedent proposition.

2.2 Connection to the Previous Discourse

Examples (3) and (5) also show that antecedents containing *denn* cannot be used to call into question the at-issue content of a previous utterance. This observation is connected to a second condition on the acceptability of conditional *denn*, namely, the presence of a *previous tacit proposal* that *p* holds.

We will explore this notion in several steps. First, we address what we mean by "presence of a proposal": conditional *denn* is unacceptable in contexts in which the antecedent proposition has not been "brought up" in any way. In the context of example (8), for instance, the proposition that Peter is coming is suggested neither by A's question, nor by the first sentence of B's utterance. In other words, neither A nor B proposed to establish that Peter is coming—that is, to update the common ground with this proposition. Therefore, conditional *denn* is bad.

(8) A: By the way, do we have any plans for the weekend?
B: Das hängt von Peter ab. Wenn er (#denn) kommt,
that depends from Peter PRT if he DENN comes
gehen wir mit ihm schwimmen.
go we with him swimming
'That depends on Peter. If he is (#DENN) coming, we'll go swimming with him.'

Second, the requirement that the proposal needs to be *tacit* has in some sense also been illustrated with (3) and (5): if speaker A utters *p*, that is, explicitly proposes *p*, speaker B cannot then express that she holds *p* to be unlikely using an antecedent containing conditional *denn*. Example (9) shows that this is also the case even if the antecedent cannot be interpreted as part of a temporal or factual conditional.

(9) A: Peter will come to my birthday.
B: #Wenn er denn kommt.
if he DENN comes
'If he DENN comes.'

In short, the antecedent proposition *p* needs to have been tacitly proposed (i.e., non-explicitly proposed) by an utterance in the discourse.[6] In example (10), this is the case: speaker A asserts a proposition *q* ('that Peter may bring his girlfriend'), which presupposes another proposition *p* (here: 'that Peter has a girlfriend'). In case it has not been previously established that Peter has a girlfriend, speaker A tacitly proposes to establish *p* in connection with his utterance. In this case, speaker B can use an antecedent containing conditional *denn* to question the validity of *p*.

[6] Conditional *denn* may be marginally acceptable in contexts where the tacit proposal was made nonverbally. We ignore such cases here.

(10) A: Peter may bring his girlfriend.
B: Wenn er denn eine hat.
if he DENN one has
'If he DENN has one.'

One final refinement has to be made: the antecedent proposition *p* does not only have to be tacitly proposed, but has to be a *necessary precondition* of the uttered proposition *q* for conditional *denn* to be acceptable. The term "necessary precondition" includes presuppositions, as well as necessary premises of defeasible inferences based on world knowledge regularities, and is not meant in a logical sense. The latter case is illustrated in (11): world knowledge suggests that A will only want to have a picnic if it is sunny.

(11) A: We will have a picnic tomorrow.
B: Wenn denn die Sonne scheint.
if DENN the sun shines
'If it is DENN sunny.'

Since the tacit proposal in (11) is based on a world knowledge regularity, it has a different origin than the tacit proposal in (9). Speaker A again asserts a proposition *q* ('that we will have a picnic tomorrow'). After hearing A's utterance, B considers what needs to be the case for A to be willing to have a picnic; one of the world knowledge based "necessary preconditions" for a successful picnic that B considers is sunny weather. Assuming that A and B did not talk about the weather for the next day yet, A's utterance—at least for B in this context—is tacitly proposing the necessary precondition that it will be sunny tomorrow. B's utterance not only makes the world knowledge regularity visible, but it also signals that B holds it being sunny the next day to be unlikely.

In sum, an interlocutor can treat any non-established proposition *p* as tacitly proposed if it can be reasonably assumed to be a precondition for another proposition *q* when *q* is uttered. Their validity can be questioned by conditional *denn*.

Regarding the placement of an antecedent containing *denn*, we observe that it occurs as close as possible to the lexical source material that gives rise to the tacit proposal (Zobel & Csipak to appear). For instance, in the self-qualification cases, the antecedent typically occurs parenthetically, as illustrated in (12), or after the consequent, as in (2).

(12)

Sein	Auto,	wenn	er	denn	eines	hat,	habe	ich	nicht	gesehen.
his	car	if	he	DENN	has	one	have	I	not	seen

'His car, if he DENN has one, I didn't see.'

When the speaker is questioning the validity of a precondition connected to a previous utterance (by herself or another participant), the antecedent either occurs before another consequent, as illustrated in (13), or bare, as in (10).

(13) [Context: It should go without saying that people from different countries can visit each other without problems.]

Und	wenn	es	denn	doch	nicht	so	selbstverständlich	sei,
and	if	it	DENN	DOCH	not	so	evident	is.SUBJ

so	verlange	sie	so	schnell	wie	möglich	Auskunft.
then	requests	she	as	fast	as	possible	information

'And if it DENN does not go without saying, she demands information as fast as possible.' (*Die Zeit*, 1992/12/25)

Tacit proposals can take various forms in addition to the presupposition and world knowledge regularity examples that are discussed in this paper. We find, for example, relativizations of word choice, choice of modal flavour, and others. For details on the corpus study on which these results are based, see Zobel & Csipak to appear.

2.3 The Effect of Adding Conditional *denn* to an Antecedent

The previous sections have illustrated what the discourse context has to look like for conditional *denn* to be acceptable. Now we turn to the contribution of *denn* itself. We do this by comparing the difference between antecedents containing *denn* and those without.

(14)

Wir	machen	morgen	ein	Picknick,	wenn	die	Sonne	scheint.
we	make	tomorrow	a	picnic	if	the	sun	shines

'We are having a picnic tomorrow if it is sunny.'

In a discourse-initial context, the speaker of (14) is suggesting to have a picnic tomorrow on the condition that it will be sunny, and there are no clues in the context about how likely the speaker believes that it will actually be sunny. In fact, the speaker can coherently follow up her utterance of (14) with *...which is likely, given the weather report*, as well as with *but I think it is unlikely*.

In contrast, an utterance containing conditional *denn* can only be followed up by the latter.

(15) Wir machen morgen ein Picknick, wenn denn die Sonne scheint.
We make tomorrow a picnic if DENN the sun shines
'We are having a picnic tomorrow if it is DENN sunny.'

By using conditional *denn*, the speaker of (15) crucially signals that she does *not* think it is likely to be sunny tomorrow. Rather, she conveys that she believes it is *unlikely* to be sunny.

Thus we predict conditional *denn* to be unacceptable in any context where the speaker either believes the antecedent is likely to be true in the actual world, or where she is completely ignorant about its probability. This is borne out. Consider a context in which the speaker lives in Florida, but her parents live in Canada. She does not regularly check up on the weather reports for her parents' location, but she knows that when the weather allows, they always have a picnic on April 15. In this case, it would be misleading to use conditional *denn* since its contribution is in conflict with the speaker's attitudes.

(16) Meine Eltern machen morgen ein Picknick, wenn (#denn) die Sonne scheint.
my parents make tomorrow a picnic if DENN the sun shines
'My parents are having a picnic tomorrow if it is (#DENN) sunny.'

3 Literature and *denn* in Conditionals vs. Questions

3.1 Preliminaries on Discourse Particles

According to Zimmermann (2011), the function of discourse particles is to fit the current utterance to the previous discourse. This results in discourse particles acting as "discourse-navigating devices," see McCready 2006, Eckardt 2013, Rojas-Esponda 2014 among others. Since discourse particles do not contribute to the truth conditions of the sentence they occur in, they supply not-at-issue material in the sense of Simons et al. (2010). We take these insights to also hold for conditional *denn*.

3.2 Analyses of Discourse Particle *denn*

With these background assumptions, we now turn to the proposals made for *denn* in the literature.

There are several descriptive proposals for the meaning of question *denn* (see König 1977, Thurmair 1989, Kwon 2005 among others). Some researchers assume that question *denn* contributes no discernible meaning but simply marks the utterance as a question (Thurmair 1991, Bayer 2012). Others do assign question *denn* a fixed contribution, but disagree on what this contribution is (e.g., Csipak & Zobel 2014, Rojas-Esponda 2015). The exact analysis of question *denn* is not relevant for the following point, though. Based on the discussion of the data in the previous section, we can already exclude that an analysis of question *denn* can be extended to account for the meaning of conditional *denn*, since conditional *denn*, but not question *denn* (*pace* Coniglio 2011, Häussler 2015), contributes a bias: the speaker believes it is unlikely that p holds in w_0.

(17) A: We are having a picnic tomorrow!

B_1: Scheint denn morgen die Sonne?
shines DENN tomorrow the sun
'Is it DENN sunny tomorrow?'

B_2: Wenn denn die Sonne scheint.
if DENN the sun shines
'If it is DENN sunny.'

While (17B_2) expresses that the speaker is reluctant to assume that it will be sunny, (17B_1) is an unbiased information question.

In the literature, conditional *denn* is discussed in Brauße 1994 and more recently in Kwon 2005, Coniglio 2011, and Häussler 2015. None of these works propose a formal analysis. One source of disagreement is whether the meaning of conditional *denn* can be unified with the other uses. Brauße and Häussler are optimistic, whereas Kwon and Coniglio, like us, are less so.

Differing in the details, the authors cited above agree that the contribution of conditional *denn* seems to be to signal the speaker's doubt about the truth of the antecedent. While intuitively appealing, this leaves open the question as to how the contribution of *denn* differs from the contribution of the conditional itself (on a standard account of conditionals, the speaker would not be committed to the truth of the antecedent in the actual world even without *denn*).

Our goal for the following section is to present a formal account of the meaning of conditional *denn* both in self-qualifying and in protest contexts, and to describe its effect on the discourse.

4 Proposal

We couch our analysis in the discourse model put forth in Farkas & Bruce 2010. We specifically choose this model since it distinguishes between offering content for update and the actual update, and provides a natural place for interlocutors to take issue with a proposed update.[7] In the following section, we first briefly present the model presented by Farkas & Bruce, and then discuss our analysis of conditional *denn*. For reasons of space, the model cannot be presented in full detail. We refer the interested reader to the original paper.

4.1 The Discourse Model

To differentiate shared commitments from the public commitments of each interlocutor, Farkas & Bruce (2010) differentiate between the common ground *cg* in the sense of Stalnaker (1978) and lists of public commitments DC_X for each individual discourse participant X. The common ground *cg* contains shared background knowledge in addition to all propo-

[7] This feature of the discourse model presented in Farkas & Bruce 2010 makes it more suitable for our purposes than the models put forth in AnderBois et al. 2010 and Murray 2014, although they have a similar scope.

sitions that the discourse participants have agreed on in the course of the conversation up until the current moment; it is a set of propositions. The individual commitment sets DC_X contain those propositions that the discourse participants committed to publicly in a previous discourse move, but which have not become part of the *cg* (yet).

The special feature of Farkas & Bruce's model is that speech acts do not directly modify the common ground. Instead, their form and (at-issue) content are first put "on the table" for negotiation. The *Table* is a stack of form-content-pairs that represent open issues that still need to be resolved among the discourse participants; in a sense, it tracks the current question under discussion (QUD, see Roberts 2012 among others).

The final component of Farkas & Bruce's model is the projected set *ps*, which is a set of sets of propositions. Each set of propositions contained in *ps* is one possible future state *s* of the *cg*, given the form-content pairs that are currently on the *Table*.

The following example illustrates the make-up of a full *context state* K_2 in the model. K_2 is the state after discourse participant A asserted the declarative sentence *Sam is home* relative to an initial context state K_1, in which the sets DC_A, DC_B, and the *Table* are empty.[8]

(18) K_2: A asserted *Sam is home* relative to K_1

A	**Table**	**B**
p	$\langle$*Sam is home*[D]:$\{p\}\rangle$	

Common Ground	**Projected Set**
$s_2 = s_1$	$ps_2 = \{s_1 \cup \{p\}\}$

(Farkas & Bruce 2010:91)

In the context-state structure, the cells below the ones containing **A** and **B** make up the public commitments of A and B, that is, DC_A and DC_B, respectively. In K_2 above, we see that after uttering *Sam is home,* A is publicly committed to p ('that Sam is home'). In addition, A's assertion put the declarative sentence and its content p on the *Table* for negotiation. Since the projected set tracks possible future states of the *cg* given what is on the *Table*, ps_2 is the result of adding p to the previous *cg* state s_1.

[8] [D] stands for the sentential feature that marks a sentence as a declarative sentence (Farkas & Bruce 2010:91).

Formally, this is done by forming the union of the set of propositions s_1 with the singleton set $\{p\}$. In contrast to ps_2, the *cg* state s_2 does not differ from s_1 since no *cg* update has been performed by A's assertion.

Importantly, B's public commitments are still empty after A's assertion. Only after discourse participant B accepts the content p of A's assertion is p added to B's set of public commitments. Once a content p is shared by all discourse participants, it is removed from their sets of public commitments and added to *cg*—that is, the set of propositions in the projected set that resulted from adding p to a previous *cg* state is reset as the current *cg* state. In case B rejects the content p of A's assertion, B is publicly committed to $\neg p$, and the discourse is "in crisis" (Farkas & Bruce 2010:89). To resolve the crisis, one discourse participant either needs to retract her public commitment, or both participants need to agree to disagree.

Farkas & Bruce's empirical aim is to model the similarities and differences between standard assertions and polar questions with respect to their effects on the discourse, both regarding what they propose and how they are taken up by another discourse participant. That is, the paper only covers the effects of *explicit proposals*. Hence to capture the conditions of use, the contribution, and the effect of conditional *denn*, we need to extend the basic model.

The central point to be addressed is the effect of tacit (i.e., non-explicit) proposals as discussed in section 2.2. Farkas & Bruce suggest that explicit proposals (i) put a new issue on the *Table*, (ii) update the public commitments of the participant who made the proposal, and (iii) project all possible future states depending on the proposal. In short, explicit proposals are invitations from the speaker to the addressee to react. What we call *tacit proposals* in this paper is markedly different: they are proposals to update the *cg* that are not put up for discussion, for instance, presupposed new content or preconditions for what has been explicitly asserted based on world knowledge rules. In a sense, tacit proposals are not "proposed" at all; a speaker who utters a sentence to which a tacit proposal is connected presumes that his interlocutors will accept the tacitly proposed content.[9,10]

[9]The process by which interlocutors accommodate presuppositions 'quietly and without fuss' is discussed in detail in von Fintel 2008.

[10]A notion similar to our tacit proposal spelled out above is explored by AnderBois et al.

We propose to implement tacit proposals as follows: assume that A utters, for instance, a declarative sentence $S[D]$ with (at-issue) content q to which a presupposition with novel content p is connected. In addition to the updates of the context state that are connected to the explicitly proposed content q, the presupposed content p is added to A's public commitments and included in the projection of ps. Example (19) illustrates the updated context state K_3 after A has asserted the declarative sentence *Sam's car is red* relative to the initial context state K_1, in which the sets DC_A, DC_B, and the *Table* are empty. The at-issue content q of *Sam's car is red* is explicitly asserted, while the content of the presupposition p (Sam has a car) is tacitly proposed.[11]

(19) K_3: A asserted *Sam's car is red* relative to K_1

A	**Table**	**B**
q $[p]$	$\langle$*Sam's car is red*[D]:$\{q\}\rangle$	
Common Ground $s_3 = s_1$	**Projected Set** $ps_3 = \{(s_1 \cup \{p\}) \cup \{q\}\}$	

In line with previous work on presupposition accommodation (e.g., von Fintel 2008) and the treatment of updates with not-at-issue content (e.g., AnderBois et al. 2010, Murray 2014), we assume that tacitly proposed con-

(2010:332f) for appositive relative clauses. They call the type of update for contents of appositives an *imposition*. While the content of appositions is assumed to be non-explicitly proposed, it does not license conditional *denn*, as is illustrated in (i). For reasons of space, we leave this issue for future work.

(i) A: Peter zahlt seiner Tochter, die ja in Wien studiert, die Wohnung.
Peter pays his daughter who JA in Vienna studies the flat
'Peter pays the rent for his daughter, who JA studies in Vienna.'
B: #Wenn sie denn in Wien studiert.
if she DENN in Vienna studies
'If she DENN studies in Vienna.'

[11] We use brackets to mark tacitly proposed material in the sets of public commitments. This is only notational sugar, since tacitly proposed content is always novel content—that is, content that does not follow from the set of public commitments of the relevant participant in the input state, and no entry on the *Table* corresponds to it.

tent is first added to the *cg* state before the corresponding at-issue content is added. This is reflected in the order in which p and q are added to the input *cg* state s_1 in ps_3.[12] Crucially, we do not assume that tacitly proposed material is immediately and automatically added to *cg*. If that were the case, the other discourse participants would not be able to take issue with tacitly proposed content at all. This is, of course, not what we find—although it is harder to address this type of content (see von Fintel 2004). We propose that tacitly proposed content is added to the *cg* together with its corresponding explicitly proposed content. In other words: if a discourse participant accepts explicitly proposed content, she automatically accepts all tacitly proposed content connected to it.

4.2 Spelling out the Proposal

There are two conditions on the use of conditional *denn* that must be met for it to be acceptable. We first formulate these two conditions with a focus on the speaker using conditional *denn*, before reframing them in terms of the discourse model introduced in the previous section.

(20) **Condition 1**
The speaker c_S does not believe that p is true in the actual world w_0, that is, he is uncommitted with respect to the truth of p in w_0.

Conditional *denn* can only felicitously occur in the antecedent p of a conditional if the speaker does not believe that p is true in w_0. This condition is trivially satisfied when *denn* occurs in the antecedent of a hypothetical conditional, but crucially *not* satisfied when *denn* occurs in the antecedent of a temporal or factual conditional (see section 2.1).

(21) **Condition 2**
The proposition p is tacitly proposed or can reasonably be inferred to be tacitly proposed by a participant α, where p is a *necessary precondition* for the validity of the content of a previous utterance by α (or a part of that utterance).

[12] One slight complication that arises here is that set union is associative and symmetric. Therefore, $(X \cup Y) \cup Z = (X \cup Z) \cup Y$. For our purposes, we would require an update function that is sensitive to the order in which propositions are added. We leave this issue for further work.

The concept of tacit proposal that we use here is as discussed in the previous subsection, a generalization of the notion of presupposed new information. In short: in any such context, any content that is not explicitly proposed qualifies as a tacit proposal. We use the term *necessary precondition* to include presuppositions, but also necessary premises of defeasible inferences based on world knowledge regularities, and do not use it in a logical sense, as discussed in section 2.2.

Let us now reframe Conditions 1 and 2 in terms of the discourse model: Since antecedents containing conditional *denn* call into question the validity of previously tacitly proposed content, it is a type of *responding move* (Farkas & Bruce 2010:106). That is, uttering an antecedent containing *denn* reacts to a preceding speech act. Hence, conditions on the use of *denn* become *conditions on the input context state* K_i that the speaker using conditional *denn* reacts to.

(22) **Condition 1 (reframed)**
For a speaker A planning to use conditional *denn* in an antecedent denoting p to react to an input context K_i, the *cg* state s_i must not entail p.

(23) **Condition 2 (reframed)**
For a speaker A planning to use conditional *denn* in an antecedent denoting p to react to an input context K_i, there has to be a participant α such that $DC_{\alpha,i}$ entail p, but no content on the *Table* entails p (i.e., $[p] \in DC_{\alpha,i}$).

When these two conditions are met, conditional *denn* can be used felicitously in the antecedent of a conditional. It contributes the following (non-truth-conditional) meaning:

(24) **Contribution of conditional *denn***
$[\![denn]\!](p) : \lambda w.\text{prob}(w,p) < T$,
where T is at or below the threshold for assertability.

In prose, the probability that p holds in w is below a given threshold of assertability T. We call this proposition $denn(p)$. We assume that in case the probability for a proposition p is below a threshold T for the speaker in a world w, the speaker believes it to be sufficiently unlikely that p holds in w

as to be unwilling to assert it. Hence, the contrast between conditional antecedents with and without *denn* is as follows: antecedents without *denn* do not explicitly signal how likely or unlikely the speaker believes it is that p holds at w_0; antecedents with *denn* express the speaker's bias (see section 2.3).

To model the effect of uttering an antecedent containing conditional *denn*, we first have to address the effect of uttering a conditional. In traditional (dynamic) semantic treatments of conditionals (following Ramsey 1931), it is assumed that the effect of a conditional is that the addressee is invited to update her beliefs with the antecedent proposition p, and if the conditional is true, she will then find that the consequent q also holds. However, this kind of treatment does not capture the intuition we have for the discourse move expressed by antecedents containing conditional *denn*. Here, it is rather the case that q has already been proposed, and the speaker is merely pointing out that in order for q to be possible to hold, it is necessary to also accept that p holds. Conditional *denn* then signals that the speaker is reluctant to accept that p holds.

Regarding the effect of antecedents containing *denn*, two cases have to be distinguished depending on whether the participant α is also the one who utters the antecedent. We first address two *protest cases* illustrated in (25) and (28), in which the person who utters the antecedent, namely the speaker c_S (= B), and α (= A) are two different people.

(25) A: Peter might bring his girlfriend.
B: Wenn er denn eine hat.
if he DENN one has
'If he DENN has one.'

Since B's responding move made by uttering an antecedent containing *denn* reacts to an immediately preceding utterance by A, the corresponding form-content-pair is on the *Table* of the current context state K_i, and $DC_{A,i}$ contains all propositions that were explicitly or tacitly proposed by A's utterance. After (25A), K_i would look as follows (assuming unrealistically that in the previous context state K_{i-1} there were no open issues):

(26) K_i: A asserted *Peter might bring his girlfriend* (=: S)

A	Table	B
q $[p]$	$\langle S[\mathrm{D}]{:}\{q\}\rangle$	
Common Ground	**Projected Set**	
$s_i = s_{i-1}$	$ps_i = \{(s_{i-1} \cup \{p\}) \cup \{q\}\}$	

We assume that B's response in (28B), a bare antecedent, is elliptical for a full conditional in which A's utterance forms the consequent: *Wenn er denn eine hat,* $\Delta_{\textit{Peter might bring his girlfriend}}$.[13] The explicitly proposed content of B's response is, therefore, a proposition r, which is the result of forming a conditional with p as the antecedent and q as the consequent. In addition to the explicitly proposed content r, B's utterance also tacitly proposes the not-at-issue content contributed by conditional *denn*: $denn(p)$. The context state K_j after (25B) is as follows:

(27) K_j: B asserted *Wenn er denn eine hat,* Δ (=: S')

A	Table	B
q $[p]$	$\langle S[\mathrm{D}]{:}\{q\}\rangle$	
	$\langle S'[\mathrm{D}]{:}\{r\}\rangle$	r $[denn(p)]$
Common Ground	**Projected Set**	
$s_j = s_i$	$ps_j = \{(((s_1 \cup \{p\}) \cup \{q\}) \cup \{denn(p)\}) \cup \{r\}\}$	

The propositions p in $DC_{A,j}$ and $denn(p)$ in $DC_{B,j}$ produce a conflict: since A is publicly committed to p, we assume that he must believe that $\lambda w.\mathrm{prob}(w, p_1) \geq T$. Speaker B, on the other hand, is publicly committed to $\lambda w.\mathrm{prob}(w, p_1) < T$. This conflict needs to be resolved in the subsequent discourse—for instance, by A's acknowledging that Peter might not have a girlfriend, and thus sharing B's opinion. In this case, A and B would in the end agree to update the *cg* only with r and $denn(p)$.

An example for a protest case in which the tacitly proposed necessary precondition is world knowledge based is given in (28), repeated from

[13] See Hardt & Romero 2004 for details and locality constraints on ellipsis across sentence and utterance boundaries.

(10). As we stated in section 2.2: after hearing A's utterance, B considers what needs to be the case for A to be willing to have a picnic; one of the world knowledge based necessary preconditions for a successful picnic that B considers is sunny weather. B chooses to address this precondition.

(28) A: We will have a picnic tomorrow.
B: Wenn denn die Sonne scheint.
if DENN the sun shines
'If it is DENN sunny.'

Hence after (28A), K_i would look as follows (assuming unrealistically that in the previous context state K_{i-1} there were no open issues):

(29) K$_i$: A asserted *We will have a picnic tomorrow* (=: S)

A	Table	B
q $[p]_B$	$\langle S[\mathrm{D}]{:}\{q\}\rangle$	

Common Ground	Projected Set
$s_i = s_{i-1}$	$ps_i = \{(s_{i-1} \cup \{p\}) \cup \{q\}\}$

From the point of view of B, A's assertion has the precondition p that it be sunny. Since Farkas & Bruce's model is designed to give an objective representation of the discourse, points of view cannot be represented well; we count this among the other desirable extensions of the model that we cannot address here. For the sake of presentation, we mark tacitly proposed content from the point of view of only one of the interlocutors by subscripting the name of that interlocutor, as in (29). In general, we assume that like the precondition p, preconditions based on other world knowledge regularities can also be treated as tacitly proposed— at least from an interlocutor's point of view who considers the world knowledge regularities connected to the utterance content.[14]

[14] We do not want to claim that a speaker or her interlocutors are always aware of the entirety of what the speaker's utterance tacitly proposes. It may even be the case that no one is aware of any of these proposals. This question is orthogonal to our story, but is explored in Biezma 2014. What is important for us is that by explicitly proposing a proposition q with preconditions $p_1 \ldots p_n$, the speaker *acts as if* she believed $p_1 \ldots p_n$ for the purpose of the discourse, and can be taken up on $p_1 \ldots p_n$ by her interlocutors. In

As before, we assume that B's answer is elliptical for a full conditional with the content r. The context state K_j after (28B) is as follows:

(30) K_j: B asserted *Wenn denn die Sonne scheint,* Δ (=: S')

A	**Table**	**B**
q $[p]_B$	$\langle S[\mathrm{D}]{:}\{q\}\rangle$	
	$\langle S'[\mathrm{D}]{:}\{r\}\rangle$	r $[denn(p)]$
Common Ground $s_j = s_i$	**Projected Set** $ps_j = \{(((s_1 \cup \{p\}) \cup \{q\}) \cup \{denn(p)\}) \cup \{r\}\}$	

After B's utterance, A becomes aware that from B's point of view, his utterance tacitly proposed p. As in the case of (25), the discourse is now in crisis since $p \in DC_{A,j}$ and $denn(p) \in DC_{B,j}$ produce a conflict. This conflict could be resolved in the subsequent discourse by A stating that he does not care about the weather when it comes to picnics.[15]

Now, we turn to a self-qualification case, illustrated in (31) and repeated from (2), in which the speaker uses an antecedent containing *denn* to qualify her own utterance.

(31) Sein Auto habe ich nicht gesehen, wenn er denn eines hat.
His car have I not seen if he DENN one has
'I didn't see his car if he DENN owns one.'

In section 2, we showed that in cases of self-qualification the antecedent containing *denn* typically follows the expression that contributes the tacit proposal that the speaker wants to qualify. In (31), this is also the case. If the speaker had only uttered the consequent without the antecedent, the definite description *sein Auto* would presuppose that "he" owns a car—that is, the speaker would commit to the proposition p that "he" owns a car. By adding the antecedent, the presupposition is *filtered* (see Karttunen 1973), and conditional *denn* conveys that the speaker is reluctant to

connection to this issue, see Condoravdi & Lauer 2011 and subsequent work.

[15] Note that B needs to believe that A's opinions regarding picnics conform to the world knowledge regularity that she considers when she utters (28B). If she knew that A does not care about good weather, it would have been odd to utter (28B).

assume p.[16] To capture this analysis in the present model, we would need to implement incremental updates of sub-clauses and their effects on the level of asserted and presupposed content. This is beyond the scope of this paper. However, we will illustrate the idea by providing the context state that would result from only uttering the consequent, given in (32), in comparison to the context state that results from the speaker's full utterance, given in (33)—assuming there were no open issues on the *Table* of $K_{\ell-1}$, the current context state at the time of utterance for either variant.

(32) K_ℓ: A asserted *Sein Auto habe ich nicht gesehen* (=: S)

A	**Table**	**B**
q $[p]$	$\langle S[\mathrm{D}]{:}\{q\}\rangle$	
Common Ground	**Projected Set**	
$s_\ell = s_{\ell-1}$	$ps_\ell = \{((s_{\ell-1} \cup \{p\}) \cup \{q\}\}$	

In (32), the speaker proposes q, with the presupposition p ('he has a car'). The addition of the antecedent containing *denn* changes both the explicitly proposed and the tacitly proposed content. In (33), the proposal is the full conditional content r, with the additional public commitment that the speaker believes it to be unlikely that p holds (i.e., *denn*(p)).

(33) K_ℓ: A asserted *Sein Auto habe ich nicht gesehen, wenn er denn eines hat* (=: S')

A	**Table**	**B**
r $[denn(p)]$	$\langle S'[\mathrm{D}]{:}\{r\}\rangle$	
Common Ground	**Projected Set**	
$s_\ell = s_{\ell-1}$	$ps_\ell = \{(s_{\ell-1} \cup \{denn(p)\}) \cup \{r\}\}$	

In (33), A is not publicly committed to the presupposed content p since the antecedent proposition, which was used to compute the proposition r denoted by the entire conditional, entails p. That is, p is filtered, and the entire conditional does not presuppose p.

[16] Presuppositions triggered by material in the consequent of a conditional are filtered in case the proposition denoted by the antecedent entails the presupposed content. For details, see Karttunen 1973.

More needs to be said on tacitly proposed necessary preconditions that are not presuppositions or based on world knowledge. For reasons of space, we have to leave these to future work. For a description, see Zobel & Csipak to appear.

5 A Particle with a Similar Function: *überhaupt*

Provided that our analysis of conditional *denn* as outlined above is correct, its discourse function is, broadly, to signal to which tacitly proposed propositions a speaker wishes to be publicly committed, and as a consequence, which updates to the common ground should be performed. The same kind of discourse move also seems to be performed by antecedents containing the discourse particle *überhaupt*. In this section, we sketch the similarities and differences between antecedents containing *denn* and *überhaupt*.

For a principled comparison with *denn*, two variants of *überhaupt* need to be distinguished: unstressed *überhaupt* and stressed *überHAUPT*.[17] Like conditional *denn*, both variants can occur in conditionals with the subordinator *wenn*, and both resist occurring in factual and temporal conditionals. In the following discussion, we provide some observations regarding the contribution of *überhaupt* and *überHAUPT* in antecedents of conditionals; a detailed analysis has to be left for further work.[18]

At first glance, antecedents containing *denn* and unstressed *überhaupt* seem very similar. Examples of conditional *denn* seem to allow substitution with *überhaupt* without a change in discourse function, as illustrated in the following example:

(34) A: I am looking forward to seeing Peter at the party tonight.
B_1: Wenn er denn kommt.
if he DENN comes

[17]*Überhaupt* can be stressed either on the first syllable (i.e., *ÜBERhaupt*) or on the second syllable (i.e., *überHAUPT*). In this paper, we will not distinguish between the two stress patterns and choose to represent stressed *überhaupt* by the latter.

[18]For a detailed look at the meaning of unembedded *überhaupt* and *überHAUPT*, we refer the reader to Rojas-Esponda 2014, 2015. Rojas-Esponda, however, explicitly puts aside embedded uses of the particle, hence *überhaupt* in conditional antecedents are not addressed in that work.

B_2: Wenn er überhaupt kommt.
if he ÜBERHAUPT comes

In the replies of both B_1 and B_2, it becomes clear that A makes an assumption (that Peter will come to the party) which B_1 and B_2 are not willing to make. Both variants call into question that Peter will come to the party.

However, a more detailed look at the distribution and meaning of unstressed *überhaupt* shows a clear difference to conditional *denn*. While conditional *denn* can be used by the speaker to qualify her own statements with no special restrictions, *überhaupt* is pragmatically odd in case the content that is qualified originates with the speaker.

(35) [Context: B tells A about an old lady who knits abstract, three dimensional forms, and who she met at a local craft fair.]

A: Interesting! What kind of abstract forms?
B: Die Künstlerin, wenn sie denn / #überhaupt eine ist,
the artist if she DENN / ÜBERHAUPT one is
orientiert sich an den frühen Kubisten.
orients herself on the early cubists
'The artist, if she DENN / #ÜBERHAUPT is one, is inspired by the early cubists.'

In (35), B decides to use the noun *Künstlerin* '(female) artist' to describe the old lady from the fair. Hence, B can be seen as the source of the tacit proposal that the old lady is an artist. In this case, conditional *denn* is fine. The use of *überhaupt* is pragmatically odd, though. It suggests that someone other than the speaker suggested that the old lady is an artist, which is in conflict with the given context.

Turning to stressed *überHAUPT*, we immediately observe that it differs from conditional *denn* in at least two respects: it can occur in shortened antecedents, and it interacts with a scalar structure.

ÜberHAUPT, unlike conditional *denn*, allows for antecedents of the form *wenn überhaupt*. These shortened antecedents are, as far as we can tell, common both in spoken and written language, as in (36).[19,20]

(36)

Viele	Buchten	und	Fjorde	sind	im	Winter,	wenn	überHAUPT,
many	bays	and	fjords	are	in.the	winter	if	ÜBERHAUPT

nur	noch	drei	bis	vier	Wochen	lang	zugefroren.
only	still	three	to	four	weeks	long	frozen.solid

'In winter, many bays and fjords are frozen solid only for three to four weeks, if that.' (*Die Zeit*, 2010/10/29)

Contexts which fulfill the conditions of use of conditional *denn* and which also provide the right environment for ellipsis require stress on the subordinator *wenn*. And yet, even if all requirements for conditional *denn* are fulfilled, the shortened combination *wenn denn* is ungrammatical.[21] For reasons of space, a detailed investigation of this observation is left for future work.

(37) a.

Peter	kommt,	WENN	er	denn	kommt,	nach	9	zur	Party.
Peter	comes	if	he	DENN	comes	after	9	to.the	party

'Peter will come, if he DENN comes, to the party after 9 p.m.'

b. *

Peter	kommt,	WENN	denn,	nach	neun	zur	Party.
Peter	comes	if	DENN	after	nine	to.the	party

Note, however, that *denn* and *überHAUPT* can be combined in the right contexts (also in shortened antecedents)—that is, in case the context and the consequent provide material that *denn* and *überHAUPT* can comment on (separately).

[19] In this and other attested examples, stress on *überhaupt* was added based on our native speaker intuitions. Unstressed *überhaupt* would be ungrammatical in these cases.

[20] The shortened antecedent seems to be elliptical for a longer version built from *wenn*, *überHAUPT*, and the backgrounded material from the consequent. For instance, the shortened antecedent in (36) plausibly stands for *wenn sie überHAUPT (für eine Zeit) zugefroren sind* 'if they froze solid (for some time) at all'.

[21] In (37b), stressed *wenn* alone would be grammatical and felicitous; as in (i).

(i)

Peter	kommt,	WENN,	nach	neun	zur	Party.
Peter	comes	if	after	9	to.the	party

'Peter will come to the party, if he comes at all, after 9 p.m.'

(38) Die Mehrzahl der Frauen mit akademischer Ausbildung wird
the majority the women with academic education will
Kinder, wenn denn überHAUPT, erst nach ihrem Studium
children if DENN ÜBERHAUPT not.until after their studies
und nach den ersten Berufserfahrungen bekommen.
and after the first professional.experience get
'The majority of women with higher education will not have children until after their studies and after they had their first professional experience, if *denn* that.' (*Die Zeit*, 2007/01/25)

The author does not want to presuppose that women with higher education will have children, hence the use of conditional *denn*. In addition, he wants to convey that the earliest expectable time for women with higher education to have children is after they finished their studies and they had worked for a time; this is conveyed by *überHAUPT*.

Using *überHAUPT* in a full or shortened antecedent of a conditional seems to highlight a quantitative or qualitative scalar structure in the consequent, or if there is none, it seems to induce one. The value selected by the consequent is signaled to be at once the highest value that can be said to hold, as well as a low value in absolute terms.

(39) Er war mittelmäßig, wenn überHAUPT.
He was mediocre if ÜBERHAUPT
'He was mediocre, if that.'

In (39), the consequent is providing a scale: students are ranked in terms of their academic achievement. The consequent proposition states that the referent is mediocre. The presence of the antecedent serves to call into question the truth of the consequent in the actual world. It also signals both that being mediocre is on the low end of the scale of achievement, and that it is the highest possible value that could be said to hold of the referent. This predicts that if *überHAUPT* is used, the highest possible value that could be assigned to a given referent cannot be the highest absolute value. This is borne out.

(40) #Er war der Beste, wenn überHAUPT.
He was the best if ÜBERHAUPT
'He was the best, if that.'

In this example, the consequent states that the referent is the best in his class on the scale of academic achievement. The use of *überHAUPT* is odd since being the best means having the maximal value on the scale, which is incompatible with being on the low end of the scale.

In (41), *überHAUPT* induces a scale on the federal states of Germany, namely, the scale of states ordered with respect to the difficulty of running into people wearing traditional costumes.

(41) Trachten bekommt man, wenn überHAUPT, in Bayern zu sehen.
traditional.costumes becomes one if ÜBERHAUPT in Bavaria to see
'One can see traditional costumes in Bavaria, if at all.'

Example (41)[22] conveys that Bavaria is the lowest on the induced scale. In other words, Bavaria is the most likely federal state in which to see traditional costumes given that the speaker takes running into people wearing them to be relatively improbable as it is.

In sum, we observe that while *denn* and *überhaupt* can both be used to emphasize that the speaker holds the content of a previous tacit proposal to be unlikely, they differ in several ways. Unlike *denn*, *überhaupt* has a stressed variant which requires access to a scalar structure in the consequent. The speaker's doubts target which value can be considered the maximal value that holds in w_0. The unstressed variant, in contrast to *denn*, requires that the issuer of the proposal that is qualified with the antecedent be someone other than the speaker.

6 Conclusion and Open Issues

In this paper, we have provided an analysis of the meaning of the German discourse particle *denn* as it occurs in the antecedent of a conditional, and

[22] See `http://www.t-online.de/reisen/reisemagazin/aktuelles/id_42379346/sid_40921024/si_0/-.html` (accessed: 2016/03/08).

we have argued that its meaning in conditionals differs enough from that in questions that it warrants a separate lexical entry. We have shown that conditional *denn* is only acceptable in contexts where there is a previous tacit proposal of the antecedent proposition p, and that moreover p is a precondition for an explicitly uttered proposition q. We have shown that conditional *denn* signals that the speaker believes the probability for p to hold in the actual world to be below a threshold value T for assertions. Finally, we have used the discourse model introduced in Farkas & Bruce (2010) to illustrate the effect conditional *denn* has on the discourse.

One open issue, among others, is the interaction of conditional *denn* with verb-first conditionals. Conditional antecedents in German can be expressed without a conditional subordinator. In this case, the antecedent clause is marked by verb-first word order. While in English only subjunctive conditionals and antecedents containing the modal *should* can be formed with verb-first word order, German allows for a much greater spectrum, as seen in (42). Now, the puzzle concerning conditional *denn* is that it can occur in all types of verb-first conditionals except for those in which the fronted verb is in the indicative mood, as in (42).

(42) a. Kommt Alex (#denn) in den nächsten Minuten, schaffen wir
comes Alex DENN in the next minutes manage we
es rechtzeitig ins Kino.
it on.time in.the cinema
'If Alex (#DENN) arrives in the next minutes, we will make it to the cinema on time.'
b. Würde Alex (denn) in den nächsten Minuten kommen,...
'If Alex (DENN) arrived in the next minutes...'
c. Sollte Alex (denn) in den nächsten Minuten kommen,...
'Should Alex (DENN) arrive in the next minutes...'
d. Wäre Alex (denn) in den nächsten Minuten gekommen,...
'Had Alex (DENN) arrived in the next minutes...'

The unacceptability of conditional *denn* in indicative verb-first conditionals is unexpected since they are restricted to hypothetical interpretations (Reis & Wöllstein 2010). Reis & Wöllstein note that verb-first conditionals show further restrictions in their distribution: the antecedents (i) cannot be postposed with respect to the consequent, (43b), or (ii) occur parenthetically inside the consequent, as shown in (43c). However, we observe that these restrictions only seem to apply to indicative verb-first conditionals, as illustrated in (44).

(43) 'If Alex comes, Maria will go for a walk.'

   a. Kommt Alex, geht Maria spazieren.
   b. ?? Maria geht, kommt Alex, spazieren.
   c. ?? Maria geht spazieren, kommt Alex.

(44) 'If Alex came, Maria would go for a walk.'

   a. Käme Alex, würde Maria spazieren gehen.
   b. Maria würde, käme Alex, spazieren gehen.
   c. Maria würde spazieren gehen, käme Alex.

In sum, we observe two classes of verb-first conditionals: non-indicative and indicative ones. The non-indicative ones share several properties with conditionals containing the subjunctor *wenn*: they allow postposed or parenthetical antecedents, and they allow conditional *denn*. Indicative verb-first conditionals do not allow either of these features. It is to be hoped that an explanation for why indicative verb-first antecedents only allow preposed antecedents will at the same time explain why conditional *denn* is not acceptable in precisely those cases.

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For-Adverbials and Aspectual Interpretation: An LTAG Analysis Using Hybrid Logic and Frame Semantics

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Abstract In this paper, we propose to use Hybrid Logic (HL) as a means to combine frame-based lexical semantics with quantification. We integrate this into a syntax-semantics interface using LTAG (Lexicalized Tree Adjoining Grammar) and show that this architecture allows a fine-grained description of event structures by quantifying, for instance, over subevents. As a case study, we provide an analysis of *for*-adverbials and the aspectual interpretations they induce. The basic idea is that *for*-adverbials introduce a universal quantification over subevents that are characterized by the predication contributed by the verb. Depending on whether these subevents are bounded or not, the resulting overall event is then an iteration or a progression. We show that by combining the HL approach with standard techniques of underspecification and by using HL to formulate general constraints on event frames, we can account for the aspectual coercion triggered by these adverbials. Furthermore, by pairing this with syntactic building blocks in LTAG, we provide a working syntax-semantics interface for these phenomena.

Keywords aspectual coercion · *for*-adverbials · iteration · Frame Semantics · Hybrid Logic · Lexicalized Tree Adjoining Grammar

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1 Introduction

1.1 *For*-Adverbials and Aspectual Reinterpretation

An important topic for theories of aspectual composition and coercion is the interaction of lexical aspect (*Aktionsart*) and temporal adverbials. On the one hand, *in*- and *for*-adverbials have been used since Vendler

(1957:145f) as indicators for distinguishing between activities and accomplishments. On the other hand, there are many types of sentences in which a temporal adverbial is not compatible with the lexical aspect of the verb but which have nevertheless a regular interpretation (see, e.g., Egg 2005). For example, while in (1a), the verb *cry* denotes an activity and is thus immediately compatible with the *for*-adverbial, the verb *cough* in (1b) is semelfactive, that is, it denotes a punctual event, and, hence, calls for additional adjustments in order to be compatible with *for*-adverbials.

(1) a. Peter cried for ten minutes.
    b. Peter coughed for ten minutes.

In the case of (1b), the adjustment consists in interpreting the sentence as describing a sequence or iteration of coughings.

The semantic composition of *for*-adverbials with atelic predicates such as *sit*, *cry* or *swim* can be modeled straightforwardly by letting the *for*-adverbial assign a certain time span to the denoted state, process or activity. Punctual and telic predicates (semelfactives, achievements, accomplishments), on the other hand, do not satisfy the sortal requirements of *for*-adverbials and, hence, need to undergo aspectual coercion when combined with such adverbials. Dölling (2014) presents an elaborate approach along these lines, which provides various coercion mechanisms for turning telic predicates into atelic ones, including the *iteration coercion* and the *habitual coercion*. For example, the iterative coercion is realized by means of the following second-order term (cf. Dölling 2014:206):

(2) $\lambda P \lambda e[\forall e'(\textit{is-constituent-of}(e', e) \rightarrow P(e'))]$

When applied to P, the resulting predicate denotes events whose constituents satisfy P. Dölling's model requires the constituents to be temporally adjacent in order to constitute a process or activity. This assumption has the consequence that semelfactives (*cough*, *knock*, *jump*), which are analyzed as *moments* without duration, need to get "stretched" to *episodes* before the iteration coercion can apply. That is, iterative interpretations of semelfactives require a two-step coercion in Dölling's approach.

While Dölling does not say much about the impact of coercion on cognitive processing costs, the approaches of Deo & Piñango (2011) and Champollion (2013) aim at being more predictive in this respect. Deo & Piñango suggest that the main processing issue for an iterative interpretation of a telic predicate, when combined with a *for*-adverbial, lies in the identification of a contextually determined regular temporal partition of the specified time span. For instance, the iterative interpretation of the sentence in (3) depends on a regular partitioning of the three months into reasonably small subintervals, each of which is associated with an event of John biking to the office.

(3) John biked to the office for three months.

Deo & Piñango do not assume that iterative readings of *for*-adverbial constructions depend on telic or atelic properties of the event description. In fact, they explicitly deny the need for inserting a coercion operator for the interpretation of expressions like (3) and (1b). However, the logical representation proposed by Deo & Piñango does not differ so much from Dölling's coercion operator in (2), except that they quantify over subintervals instead of event constituents. The crucial point is that for Deo & Piñango, the quantification is already introduced by the *for*-adverbial, irrespective of the type of predicate it applies to. Deo & Piñango distinguish between *iterative* and *continuous* readings of *for*-adverbials, where a continuous reading requires an atelic predicate as in (1a). They assume that iterative readings call for a contextually determined partition of the time interval while continuous readings go along with a context-independent "infinitesimal" partition.

Under this analysis, iterative readings do indeed not depend on the telicity or atelicity of the predicate. Continuous interpretations, however, are apparently sensitive to the aspectual properties of the verb since they are licensed by atelic predicates only. Champollion (2013) takes up this issue and provides further evidence for the fact that the missing aspectual sensitivity in Deo & Piñango's approach leads to undesired consequences. Champollion tries to remedy these problems by the following modifictions: first, he postulates a silent iteration operator, which means "once or repeatedly," that turns semelfactive and telic predicates into atelic ones. Second, he assumes that *for*-adverbials introduce a vague but context-independent partition $\mathscr{R}_I^{short(I)}$ of the specified temporal interval I into reasonably short subintervals The meaning of an adverbial like *for three months* is then represented as follows (cf. Champollion 2013:445):

(4) $\lambda P \lambda I[months(I) = 3 \wedge AT(P, I) \wedge \forall J[J \in \mathcal{R}_I^{short(I)} \rightarrow AT(P, J)]]$

Here, $AT(P, I)$ roughly means that P holds at I, which in the case of event predicates comes down to saying that there is an event of type P whose runtime is I. Since (4) requires P to hold at the whole interval and at each cell of the partition, it follows that P is *not quantized* (in the sense of Krifka 1998); hence, it is not telic. That is, *for*-adverbials select atelic predicates according to Champollion's analysis, which is the reason for applying the iteration operator in the case of telic predicates. Note that the partition of the interval can be coarser than the decomposition of the iteration into elementary events; repetitions may occur within a single cell of the partition. If, for example, I is an interval of 10 minutes and $\mathcal{R}_I^{short(I)}$ consists of cells of 30 seconds then (1b) is true if one or more coughings of Peter occur within each of the 30 second cells (under the above assumption that the silent iteration operator has been applied to the semelfactive predicate).

The described analysis is problematic for examples like (3) since the partition $\mathcal{R}_I^{short(I)}$ is independent of the context. In (3), it is not clear whether John biked to the office every day, twice a day, every second day, every week, or according to another schedule. It can thus happen that there is no biking of John to the office in some of the cells of $\mathcal{R}_I^{short(I)}$. This is why the partition operator of Deo & Piñango has a contextual parameter. Champollion (2013:446) also postulates a separate, context-dependent partition operator, but only for situations where the reference of indefinites covaries with the cells of the partition, as in example (5a).

(5) a. We built a huge snowman in our front yard for several years.
b. She bounced a ball for twenty minutes.

Zucchi & White (2001) and Kratzer (2007), among others, observed that *for*-adverbials tend to take narrow semantic scope with respect to the quantifiers in their syntactic scope. This implies a non-covarying interpretation of indefinites as in (5b). The narrow-scope covariation of the indefinite in the preferred reading of (5a) is thus an exception that calls for an explanation. Champollion's suggestion to put the burden at least partly on an additional, contextually specified partition seems problematic since the contextual parameter is already required for examples like (3), as mentioned above.

1.2 Goals and Outline

In this paper, we present a revised analysis of *for*-adverbials and develop a formal model of their compositional integration at the syntax-semantics interface. The proposed semantic representation combines several aspects of the approaches discussed in the previous section: like Dölling, we directly refer to event components instead of temporal subintervals. Similar to Deo & Piñango and Champollion, we assume that the universal quantification over event components is already contributed by the *for*-adverbial. Like Dölling and Deo & Piñango, we do not postulate an iteration operator. Like Dölling and Champollion, we take into account the aspectual sensitivity of *for*-adverbials. The semantic representations used in this paper are motivated by frame-semantic considerations and will be formalized in the language of *Hybrid Logic* (HL). This language allows us to express constraints over event types and to quantify over event components. The syntax-semantics interface is modelled within the framework of *Lexicalized Tree Adjoining Grammar* (LTAG) combined with underspecification on the level of HL formulas.

The structure of the paper is as follows. Section 2 introduces HL as a language for describing frame structures. Section 3 describes the architecture used for modelling the syntax-semantics interface. Within this framework, section 4 develops then an analysis of *for*-adverbials in combination with a uniform treatment of iteration and progression, along the lines sketched above. Section 5 concludes.

2 Semantic Frames and Hybrid Logic

2.1 Semantic Frames

Frames emerged as a representation format of conceptual and lexical knowledge (Fillmore 1982, Barsalou 1992, Löbner 2014). They are commonly presented as semantic graphs with labelled nodes and edges, as in figure 1, where nodes correspond to entities (individuals, events, …) and edges to (functional or non-functional) relations between these entities. In figure 1 all relations except *part-of* are meant to be functional. This representation offers a fine-grained and systematic decomposition of meaning that goes beyond what is usually represented in FrameNet frames (Osswald & Van Valin Jr. 2014). Frames can be formalized as extended typed feature structures (Petersen 2006, Kallmeyer & Osswald 2013) and specified as models of a suitable logical language, the *labelled attribute-value description language* (LAVD language). Such a language allows for the composition of lexical frames on the sentential level by means of an explicit syntax-semantics interface (Kallmeyer & Osswald 2013). Yet, this logical framework does not provide means for the lexical items to introduce explicit quantification.

As Blackburn (1993) points out, attribute-value structures can also be described using another logical language: *Hybrid Logic* (HL, see Areces & ten Cate 2007), an extension of the language of modal logic, well-suited to the description of graph structures like the one of figure 1. HL introduces *nominals*, that is, node names, that allow the logical formulas to refer to specific nodes of the graph. The nominal n_0 for instance refers to the *locomotion* node in figure 1. It is then possible, for example, to specify that the AGENT and the MOVER edges from the node n_0 should meet on the same node in figure 1. This additional expressiveness of HL over modal logic allows one to express node sharing in attribute-value structures (Blackburn 1993). HL is an established logical formalism which has been extensively studied, in particular with respect to the addition of *variables* for nodes, and the associated *quantifiers*, that can appear in the logical formulas. Its relation to attribute-value structures and its expressiveness make it a natural candidate to relate quantified expressions and frame semantics.

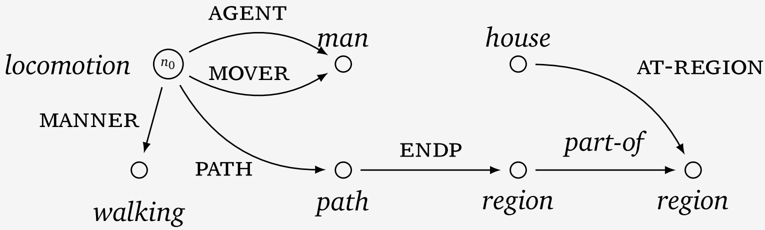

Figure 1 Frame compatible with the sense of *The man walked to the house* (adapted from Kallmeyer & Osswald 2013)

Compared to Kallmeyer & Osswald 2013, the approach we propose here does not consider frames as "genuine semantic representations." The one-to-one equivalence between the logical formulas of the LAVD language of Kallmeyer & Osswald (2013) and the frames as graph (or relational) structures relies on the existence of minimal models for such formulas. While HL with nominals, but without variables and binders, is very close to the LAVD language, it is not obvious what the notion of minimal model becomes when using quantification. Thus, we have a more traditional view where the sense of an expression is a hybrid logical formula and its reference is computed against models. The latter are the frames we wish to consider. But, contrary to what happens with minimal models, they are then not fully specified by the logical formulas which serve as frame descriptions.

2.2 Frame Description with Hybrid Logic

Before giving the formal definition of Hybrid Logic as used in this paper, let us illustrate the different possibilities HL offers to express properties of frames. Consider the model $\mathscr{M}_1$ given in figure 1. In this model, we have edges labeled with functional relations (AGENT, MOVER etc.) and one edge labeled with a non-functional relation, *part-of*, indicated by lowercase. (Note that HL formulas do not distinguish between the two types of edge labels. That is, functionality has to be enforced by additional contraints.) As in standard modal logic, we can talk about propositions holding at single nodes. This allows for specifying types, in the Frame Semantics sense, assigned to single nodes as *proposition*. For instance, in $\mathscr{M}_1$, the formula *region* is true at the two nodes in the bottom-right corner but false at all other nodes of $\mathscr{M}_1$. Furthermore, we can talk about the existence of an attribute for a node. This corresponds to stating there exists an edge originating at this node using the $\Diamond$ modality in modal logic. In frames, there may be several relations, hence several modalities, denoted by $\langle R \rangle$ where R is the name of the relation. For example, $\langle \textsc{agent} \rangle man$ is true in $\mathscr{M}_1$ at the *locomotion* node n_0 because there is an AGENT edge from n_0 to some other node where *man* holds. But it is false at all other nodes. Finally, we can have conjunction, disjunction, and negation of these formulas. For example, $locomotion \wedge \langle \textsc{manner} \rangle walking \wedge \langle \textsc{path} \rangle \langle \textsc{endp} \rangle \top$ is also true at the *locomotion* node n_0.[1]

HL extends this with the possibility to name nodes in order to refer back to them without following a specific path, and with quantification over nodes. Let us exemplify this again with formulas evaluated with respect to $\mathscr{M}_1$. In the following, we use a set of nominals, that is, of node names, and a set of node variables. n_0 is such a nominal, the node assigned to it is the locomotion node in $\mathscr{M}_1$. $x, y, \ldots$ are node variables. The truth of a formula is given with respect to a specific node w of a model $\mathscr{M}$, an assignment V from nominals to nodes in the model and an assignment g which maps variables to nodes in $\mathscr{M}$.

There are different ways to state existential quantifications in HL, for instance, $\mathbf{\exists}\phi$ and $\exists x.\phi$. $\mathbf{\exists}\phi$ is true at w if there exists a node w' in $\mathscr{M}$ at which ϕ holds. In other words, we move to some node w' in the frame and there ϕ is true. $\mathbf{\exists}$*house* is, for instance, true at any node in $\mathscr{M}_1$. As usual, we define $\mathbf{\forall}\phi \equiv \neg\mathbf{\exists}(\neg\phi)$. Then $\mathbf{\forall}(\mathit{path} \rightarrow \langle \textsc{endp} \rangle \top)$ holds at any node in $\mathscr{M}_1$. In contrast to $\mathbf{\exists}\phi$, $\exists x.\phi$ is true at w if there is a w' such that ϕ is true at w under an assignment $g^x_{w'}$ which maps x to w'. In other words, there is a node that we name x but for the evaluation of ϕ, we do not move to that node. For example, the formula $\exists x.\langle \textsc{path} \rangle \langle \textsc{endp} \rangle \langle \mathit{part\text{-}of} \rangle (x \wedge \mathit{region}) \wedge \mathbf{\exists}(\mathit{house} \wedge \langle \textsc{at-region} \rangle x)$ is true at the *locomotion* node in $\mathscr{M}_1$.

Besides quantification, HL also allows us to use nominals or variables to refer to nodes: $@_n\phi$ specifies the moving to the node w denoted by n before evaluating ϕ. n can be either a nominal or a variable. The $\downarrow$ operator allows us to assign the current node to a variable: $\downarrow x.\phi$ is true at w if ϕ is true at w under the assignment g^x_w. That is, we call the node we are located at x, and, under this assignment, ϕ is true at that node. For example, $\langle \textsc{path} \rangle \langle \textsc{endp} \rangle \langle \mathit{part\text{-}of} \rangle (\downarrow x.\mathit{region} \wedge \mathbf{\exists}(\mathit{house} \wedge \langle \textsc{at-region} \rangle x))$ is true at the *locomotion* node in $\mathscr{M}_1$.

By employing this logic, we can characterize the frame of figure 1 by the formula (6). More precisely, any model that satisfies formula (6) can

[1] $\top$ is the proposition that is true at any node. So $\langle \textsc{path} \rangle \langle \textsc{endp} \rangle \top$ is true at a node if we can reach from it some node following first a PATH edge then a ENDP edge.

be unified with the frame of figure 1 at node n_0.

(6) $@_{n_0} locomotion$
$$\wedge\, (\exists x.\langle \text{AGENT}\rangle(x \wedge man) \wedge \langle \text{MOVER}\rangle x)$$
$$\wedge\, \langle \text{MANNER}\rangle walking$$
$$\wedge\, (\exists x.\langle \text{PATH}\rangle(path \wedge \langle \text{ENDP}\rangle(region \wedge \langle \textit{part-of}\,\rangle(x \wedge region)))$$
$$\wedge\, \mathbf{\exists}(house \wedge \langle \text{AT-REGION}\rangle x))$$

Alternatively, as shown in (7), we can use the $\downarrow$ operator instead of the two $\exists$ operators since we know how to reach the two nodes we want to refer to several times. The first time we talk about them, we give them some name via the $\downarrow$ operator and this allows to refer to them again at some later point.

(7) $@_{n_0} locomotion$
$$\wedge\, \langle \text{AGENT}\rangle(\downarrow x.man \wedge @_{n_0}\langle \text{MOVER}\rangle x)$$
$$\wedge\, \langle \text{MANNER}\rangle walking$$
$$\wedge\, \langle \text{PATH}\rangle(path \wedge \langle \text{ENDP}\rangle(region \wedge \langle \textit{part-of}\,\rangle(\downarrow x.region$$
$$\wedge\, \mathbf{\exists}(house \wedge \langle \text{AT-REGION}\rangle x))))$$

As can be seen from this example, HL allows us to express path equations (see the $\langle \text{AGENT}\rangle$ and $\langle \text{MOVER}\rangle$ attributes of n_0). However, the way these path equations are expressed is rather tedious compared to other feature logics. Therefore we define

$$\langle \text{R}^1_1\rangle \ldots \langle \text{R}^1_k\rangle \doteq \langle \text{R}^2_1\rangle \ldots \langle \text{R}^2_l\rangle \equiv \exists x(\langle \text{R}^1_1\rangle \ldots \langle \text{R}^1_k\rangle x \wedge \langle \text{R}^2_1\rangle \ldots \langle \text{R}^2_l\rangle x)$$

Using this notation, the HL characterization of $\mathscr{M}_1$ is (8).

(8) $@_{n_0} locomotion$
$$\wedge\, \langle \text{AGENT}\rangle \doteq \langle \text{MOVER}\rangle$$
$$\wedge\, \langle \text{AGENT}\rangle man$$
$$\wedge\, \langle \text{MANNER}\rangle walking$$
$$\wedge\, \langle \text{PATH}\rangle(path \wedge \langle \text{ENDP}\rangle(region \wedge \langle \textit{part-of}\,\rangle(\downarrow x.region$$
$$\wedge\, \mathbf{\exists}(house \wedge \langle \text{AT-REGION}\rangle x))))$$

2.3 Hybrid Logic

We slightly adapt the notations of Areces & ten Cate (2007).

Definition 1 (Formulas) *Let* $\mathsf{Rel} = \mathsf{Func} \cup \mathsf{PropRel}$ *be a set of functional and non-functional relation symbols,* Type *a set of type symbols,* Nom *a set of nominals (node names), and* Nvar *a set of node variables, with* $\mathsf{Node} = \mathsf{Nom} \cup \mathsf{Nvar}$. *Formulas are defined as:*

$$\mathsf{Forms} ::= \top \mid p \mid n \mid \neg\phi \mid \phi_1 \wedge \phi_2 \mid \langle R \rangle \phi \mid \mathbf{E}\phi \mid @_n\phi \mid \downarrow x.\phi \mid \exists x.\phi$$

where $p \in \mathsf{Type}$, $n \in \mathsf{Node}$, $x \in \mathsf{Nvar}$, $R \in \mathsf{Rel}$ *and* $\phi, \phi_1, \phi_2 \in \mathsf{Forms}$. *Moreover, we define:*

- $\mathbf{A}\phi \equiv \neg\mathbf{E}\neg\phi$
- $[R]\phi \equiv \neg\langle R \rangle\neg\phi$
- $\phi \rightarrow \psi \equiv \neg\phi \vee \psi$
- $\langle R_1^1 \rangle \ldots \langle R_k^1 \rangle \doteq \langle R_1^2 \rangle \ldots \langle R_l^2 \rangle \equiv \exists x(\langle R_1^1 \rangle \ldots \langle R_k^1 \rangle x \wedge \langle R_1^2 \rangle \ldots \langle R_l^2 \rangle x)$

We call $\mathbf{A}$ *and* $[R]$ *universal operators, and* $\mathbf{E}$ *and* $\langle R \rangle$ *existential operators. The elements of* Func *will be written in small caps.*

Definition 2 (Model, assignment) *A* model $\mathcal{M} = \langle M, (R^{\mathcal{M}})_{R \in \mathsf{Rel}}, V \rangle$ *is a triple such that*

1. *M is a non-empty set,*
2. *each $R^{\mathcal{M}}$ is a binary relation on M, and*
3. *the valuation $V : \mathsf{Type} \cup \mathsf{Nom} \longrightarrow \wp(M)$ is such that if $i \in \mathsf{Nom}$ then $V(i)$ is a singleton.*

An assignment *g is a mapping $g : \mathsf{Nvar} \longrightarrow M$. For an assignment g, g_m^x is an assignment that differs from g at most on x and $g_m^x(x) = m$. For $n \in \mathsf{Node}$, we also define $[n]^{\mathcal{M},g}$ to be the only m such that $V(n) = \{m\}$ if $n \in \mathsf{Nom}$ and $[n]^{\mathcal{M},g} = g(n)$ if $n \in \mathsf{Nvar}$.*

As can be seen from these definitions, nominals are, on the one hand, similar to variables since they allow us to access nodes via the @ operator, and on the other hand, they are similar to propositions, that is, to types, except that they are special propositions that hold only at a single node.

Now we can define satisfaction of a formula at a specific node in a model, given some assignment g.

Definition 3 (Satisfaction)

1. *Let* $\mathcal{M}$ *be a model,* $w \in M$*, and* g *an assignment for* $\mathcal{M}$*. The satisfaction relation of a formula* ϕ *by the model* $\mathcal{M}$*, with the assignment* g *at the node* w *(*$\mathcal{M}, g, w \vDash \phi$*) is defined as follows:*

$\mathcal{M}, g, w \vDash \top$	
$\mathcal{M}, g, w \vDash p$	*iff* $w \in V(p)$ *for* $p \in \mathsf{Type}$
$\mathcal{M}, g, w \vDash n$	*iff* $w = [n]^{\mathcal{M},g}$ *for* $n \in \mathsf{Node}$
$\mathcal{M}, g, w \vDash @_n\phi$	*iff* $\mathcal{M}, g, [n]^{\mathcal{M},g} \vDash \phi$ *for* $n \in \mathsf{Node}$
$\mathcal{M}, g, w \vDash \neg\phi$	*iff* $\mathcal{M}, g, w \nvDash \phi$
$\mathcal{M}, g, w \vDash \downarrow x.\phi$	*iff* $\mathcal{M}, g^x_w, w \vDash \phi$
$\mathcal{M}, g, w \vDash \phi_1 \wedge \phi_2$	*iff* $\mathcal{M}, g, w \vDash \phi_1$ *and* $\mathcal{M}, g, w \vDash \phi_2$
$\mathcal{M}, g, w \vDash \exists x.\phi$	*iff* $\exists w'\ \mathcal{M}, g^x_{w'}, w \vDash \phi$
$\mathcal{M}, g, w \vDash \langle R \rangle\phi$	*iff* $\exists w'\ R^{\mathcal{M}}(w, w')$ *and* $\mathcal{M}, g, w' \vDash \phi$
$\mathcal{M}, g, w \vDash \boldsymbol{\exists}\phi$	*iff* $\exists w'\ \mathcal{M}, g, w' \vDash \phi$

2. *A formula* ϕ *is:*
   - satisfiable *if there is a model* $\mathcal{M}$*, and assignment* g *on* $\mathcal{M}$*, and a node* $w \in M$ *such that* $\mathcal{M}, g, w \vDash \phi$*;*
   - globally true *in a model* $\mathcal{M}$ *under an assignment* g*, that is,* $\mathcal{M}, g, w \vDash \phi$ *for all* $w \in M$*. We write* $\mathcal{M}, g \vDash \phi$*.*

With these definitions, we also obtain

$$\mathcal{M}, g, w \vDash \boldsymbol{\forall}\phi \text{ iff } \forall w'\ \mathcal{M}, g, w' \vDash \phi$$

2.4 Expressive Power

According to the satisfaction relation definition, $\downarrow$ and $\exists$ bind node variables without changing the current evaluation node. In addition to $\boldsymbol{\exists}$, Blackburn & Seligman (1995) introduce another quantifier Σ for which the satisfaction relation also changes the evaluation node:[2]

$$\mathcal{M}, g, w \vDash \Sigma x.\phi \text{ iff } \exists w'\ \mathcal{M}, g^x_{w'}, w' \vDash \phi$$

[2]Blackburn & Seligman (1995) call $\boldsymbol{\exists}$ the *somewhere* operator, and write it $\Diamond$, and $\boldsymbol{\forall}$ is the *universal* modality, written $\Box$.

This defines two independent families of operators: $\downarrow$ and $\exists$, and $\boldsymbol{\exists}$ and Σ.[3] However, using any operators of both families (for instance $\downarrow$ and $\boldsymbol{\exists}$, the "weakest" ones) is expressively equivalent to using the most expressive fragment of the hybrid languages (the full hybrid language).

It is usual to refer to the hybrid languages $\mathscr{H}(\theta_1, \ldots, \theta_n)$ as the extension of the modal language with nominals and the operators $\theta_1, \ldots, \theta_n \in \{\downarrow, @, \boldsymbol{\exists}, \exists\}$. It is worth noting that even using the simplest binder $\downarrow$ already causes the satisfiability problem for $\mathscr{H}(\downarrow)$ to be undecidable (Areces et al. 1999). There are, however, syntactic restrictions on formulas that make the satisfiability problem decidable. In particular, formulas of the full hybrid language that do not contain the pattern "universal operator scoping over a $\downarrow$ operator scoping over a universal operator" have a decidable satisfiability problem (ten Cate & Franceschet 2005). All of the formulas we build in our account of iteration and progression in combination with *for*-adverbial avoid this pattern. This might not be the case in the general use of HL for quantification by Kallmeyer et al. (2015) in sentences such as *every politician in every city…* However, for every hybrid language, testing a given formula against a given model remains decidable (Franceschet & de Rijke 2006).

3 The Syntax-Semantics Interface for LTAG and HL

3.1 Introduction to LTAG

A *Lexicalized Tree Adjoining Grammar* (LTAG; Joshi & Schabes 1997, Abeillé & Rambow 2000) consists of a finite set of *elementary trees*. Larger trees can be derived via the composition operations *substitution* (replacing a leaf with a tree) and *adjunction* (replacing an internal node with a tree). An adjoining tree has a unique non-terminal leaf that is its *foot node* (marked with an asterisk). When adjoining such a tree to some node *n*, in the resulting tree, the subtree with root *n* from the original tree ends up below the foot node. A sample LTAG derivation is given in figure 2. The subject and object NP slots in the *ate* tree are replaced with the *Peter* and *pizza* trees respectively (*substitution*) and the *always* tree adjoins at the VP node of the *ate* tree.

[3] Note that $\downarrow$ can be defined in terms of $\exists$ by $\downarrow x.\phi \equiv \exists x.x \wedge \phi$ and that $\boldsymbol{\exists}$ can be defined in terms of Σ by $\boldsymbol{\exists}\phi \equiv \Sigma z.\phi$ with z not occurring in ϕ.

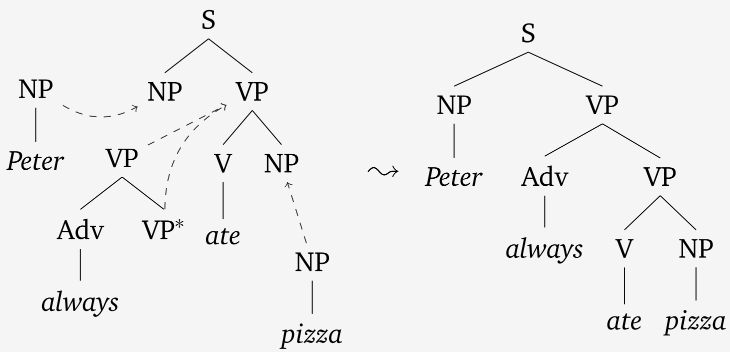

Figure 2 Sample LTAG derivation

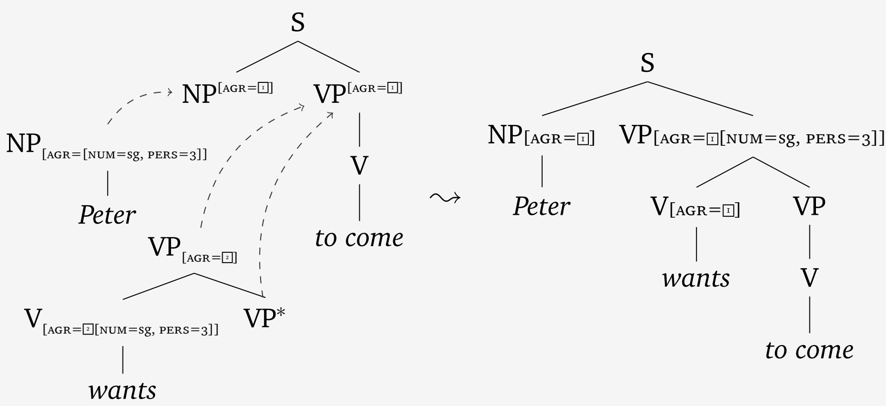

Figure 3 LTAG derivation with feature structures

In order to capture syntactic generalizations, the non-terminal node labels are enriched with feature structures (Vijay-Shanker & Joshi 1988). Each node has a top and a bottom feature structure (except substitution nodes, which have only a top). Nodes in the same elementary tree can share features. Substitutions and adjunctions trigger unifications: in a substitution step, the top of the root of the substituted tree unifies with the top of the substitution node. In an adjunction step, the top of the root of the adjoining tree unifies with the top of the adjunction site and the bottom of the foot of the adjoining tree unifies with the bottom of the adjunction site. Furthermore, in the final derived tree, top and bottom must unify in all nodes. Figure 3 provides an example (top feature structures are superscripts and bottom feature structures are subscripts). The AGR feature of the V node of *wants* is passed to the root of the auxiliary tree. Then, by adjunction and subsequent top-bottom unification on the highest VP node, its value unifies with $\boxed{1}$ in the *to come* tree and thereby gets passed to the subject node. By substitution and subsequent top-bottom unification at the NP slot, it unifies then with the AGR feature at the root of the *Peter* tree. The tree on the right is the one we obtain after derivation and top-bottom unification on all nodes.

3.2 The Syntax-Semantics Interface

Our architecture for the interface between TAG syntax and frame semantics builds on previous approaches which pair each elementary tree with a semantic representation that consists of a set of formulas, in this case, HL formulas. An example is given in figure 4. We use interface features on the syntactic nodes that are responsible for triggering semantic composition via the feature unifications during substitution and adjunction. These features are, for instance, I (for "individual") and E (for "event"). Their values can be nominals or variables from the HL formula linked to the elementary tree they occur in. If their values are not yet known, we can use a boxed number as a variable and indicate structure sharing via this variable. These boxed numbers can also occur in the HL formulas. Once a value is assigned to them via syntactic composition, their occurrence in the HL formula is also replaced with this value. This unification-based assignment is the only mechanism for semantic composition.

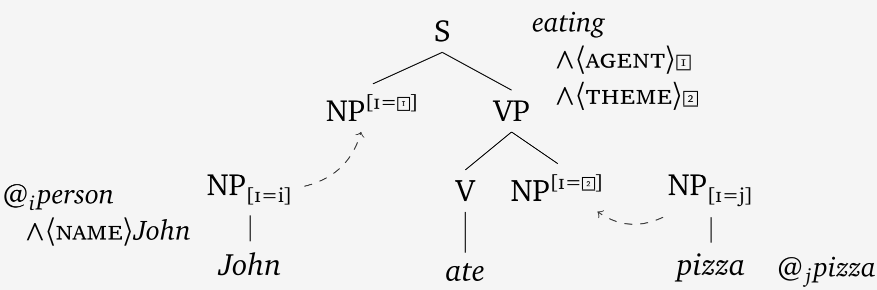

Figure 4 HL-based syntax-semantics interface

The example in figure 4 is rather simple. The elementary tree of *ate* and its associated HL formula tell us that the nominal or variable of the AGENT node is contributed by whatever is substituted at the subject node while the THEME node will be further specified by the object NP. Both NP trees contain a nominal and contribute this nominal via the I interface feature. Substitution and final top-bottom unification unify [I=$\boxed{1}$] with [I=i] and [I=$\boxed{2}$] with [I=j]. As a consequence, i is assigned to $\boxed{1}$ and j to $\boxed{2}$ and we obtain a collection of three HL formulas, $eating \wedge \langle \text{AGENT} \rangle i \wedge \langle \text{THEME} \rangle j$, $@_i person \wedge \langle \text{NAME} \rangle John$ and $@_j pizza$. These are then interpreted conjunctively.

3.3 Underspecified Representations

In figure 4, the boxed variables in the HL formulas act like holes that are replaced with concrete formulas (here, the two nominals) once the syntax-triggered unifications are performed. In general, we want to be able to insert also other formulas into these holes, not just variables and nominals. Therefore, we introduce the possibility to label HL formulas, using labels l_0, l_1, etc. A label is the name of a unique HL formula. But it does not, as in the case of nominals, denote a single element in the frame; the formula can hold at several frame nodes. Using these labels as values in our interface features, we can insert these formulas in larger formulas via composition. Besides these labels, we also introduce the possibility to express dominance constraints of the form $\boxed{i} \lhd^* x$ where x is either a boxed variable (= a hole) or a label. The relation $\lhd^*$ is the dominance relation in the syntactic tree of the HL formula $\boxed{i}$ occurs in, that is, it expresses a relation "is subformula of" on the HL formulas. This extension is an application of well-known underspecification techniques, in particular *hole semantics* (Bos 1995). Similar proposals for LTAG semantics but with standard predicate logic and not with frames and HL have already been made by Gardent & Kallmeyer (2003), Kallmeyer & Joshi (2003), and Kallmeyer & Romero (2008).

As a basic example, consider the derivation given in figure 5. The *every* tree adjoins to the root of the *dog* tree and the derived tree substitutes into the subject slot of the *barked* tree. The interface feature MINS determines the minimal scope for attaching quantifiers, and the feature E stands for the event/predication contributed at a specific node. The syntactic unifications lead to $\boxed{4} = x$, $\boxed{2} = l_2, \boxed{3} = l_1$. As a result of these equations, we

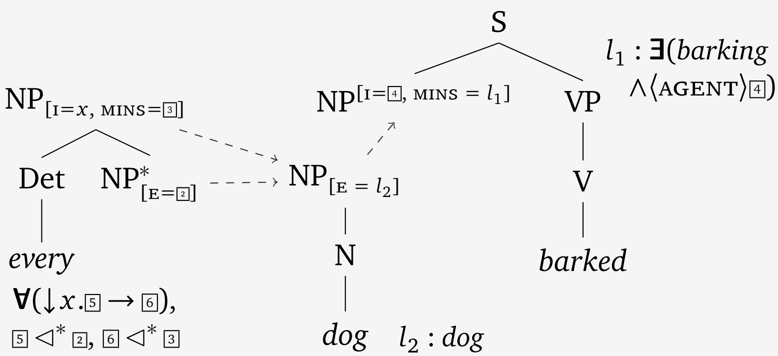

Figure 5 Derivation of *every dog barked*

obtain the following underspecified representation:

(9) $\forall(\downarrow x.\boxed{5} \rightarrow \boxed{6}), l_2 : dog, l_1 : \exists(barking \wedge \langle\textsc{agent}\rangle x), \boxed{5} \lhd^{*} l_2, \boxed{6} \lhd^{*} l_1$

The representation in (9) has a unique solution (i.e., a unique fully specified HL formula that satisfies the constraints in (9)) given by the mapping $\boxed{5} \mapsto l_2, \boxed{6} \mapsto l_1$, which leads to (10).

(10) $\forall(\downarrow x.dog \rightarrow \exists(barking \wedge \langle\textsc{agent}\rangle x))$

Obviously, this way to underspecify subformula relations in the semantic representation allows standard underspecified representations for scope ambiguities.

In the next section, we will see that underspecification via dominance constraints also allows us to account for cases in event semantics where certain characterizations of events are underspecified as to whether they refer to the entire event or to subevents. The particular combination of frame description in HL and underspecification brings sufficient expressive power to (a) allow for a fine-grained event decomposition and for quantification over subevents, and (b) link embedded subevents and the entire event via dominance constraints and thereby enable adverbials to apply in-between. Furthermore, underspecification in the event types, in combination with appropriate HL constraints, allows us to underspecify the type of the event resulting from applying a *for*-adverbial while making this type dependent on the type of the embedded event.

Besides frame descriptions linked to elementary trees, our grammar also contains general constraints on frames that hold universally and independently of syntax. These constraints can, for instance, describe subtype relations of the form $\forall locomotion \rightarrow motion$; mandatory attributes for certain types, such as $\forall motion \rightarrow \langle \textsc{mover} \rangle \top$; or mandatory path equations for certain types, for example $\forall locomotion \rightarrow \langle \textsc{agent} \rangle \doteq \langle \textsc{mover} \rangle$.

4 Application to *for*-Adverbials

4.1 *For*-Adverbials and Atelic Events

We start with a basic case of a *for*-adverbial modifying an atelic event description:

(11) Peter swam for one hour.

We take *swimming* to be represented by a frame described by $swimming \wedge \langle \textsc{agent} \rangle \boxed{2}$. Furthermore, we need an existential quantification over the event such that the semantic representation for *Peter swam*, for instance, is $@_i(person \wedge \langle \textsc{name} \rangle Peter) \wedge \exists (swimming \wedge \langle \textsc{agent} \rangle i)$. This existential quantifier does not necessarily immediately embed the event characterization coming from the verb since some adverbial taking this event node into its scope could attach to it. Therefore, we assume a kind of event-internal scope window between the existential quantification and the event node. Figure 6 shows the *swam* tree with its HL formula. In the formula, there is a hole $\boxed{3}$ in the scope of the existential $\exists$, and the formula labeled l_2, which describes the *swimming* node, has to be below $\boxed{3}$ (constraint $\boxed{3} \triangleleft^* l_2$). If no adverbial is added, then l_2 gets assigned to $\boxed{3}$.

We assume that *swimming* is a subtype of the event type *progression*, which characterizes continuous nonbounded events:[4]

(12) $\forall (swimming \rightarrow progression)$
$\forall (progression \rightarrow nonbounded)$

[4] We prefer "*non*bounded" over "*un*bounded" in order to avoid the connotation of limitlessness that comes with the latter term (see also Jackendoff 1996). For purposes of this paper, we do not distinguish between atelicity and nonboundedness but we are aware that there are good reasons to do so in general (see, for instance, Cappelle & Declerck 2005 and the references therein).

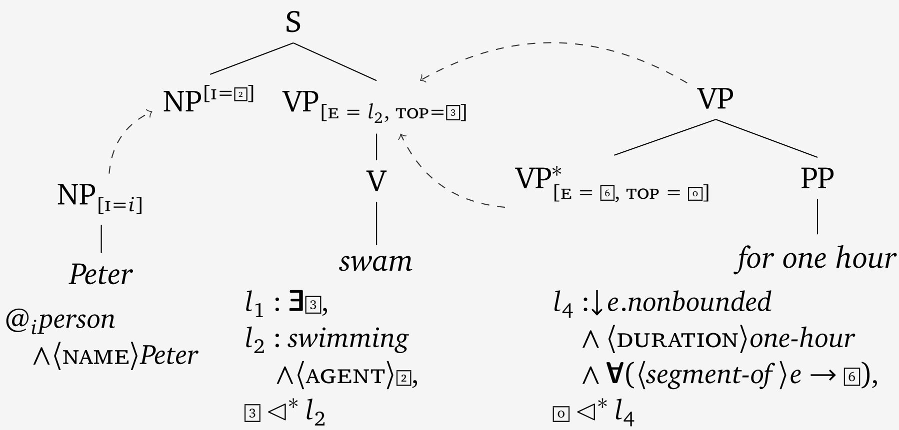

Figure 6 Derivation for (11)

Following the outline sketched in section 1.2, the meaning of the adverbial *for one hour* is represented as follows:[5]

(13) $\downarrow e.\mathit{nonbounded} \wedge \langle \textsc{duration} \rangle \mathit{one\text{-}hour} \wedge \forall(\langle \mathit{segment\text{-}of} \rangle e \rightarrow P)$

More precisely, (13) is paired with an elementary tree, as depicted in the right of figure 6, and P stands for a hole (in this case, $\boxed{6}$), which will be filled by the formula associated with the modified VP, here l_2.

We may assume that events of type *progression* have a sufficently rich subeventual structure that is closed under sum formation. For the present purpose, we only need the property that every progression is an event segment of itself:

(14) $\forall(\downarrow e.\mathit{progression} \rightarrow \langle \mathit{segment\text{-}of} \rangle e)$

[5]As pointed out by an anonymous reviewer, formula (13) could be expressed equivalently in the following, more compact form by employing the universal modality and the inverse of the relation *segment-of*:

$$\mathit{nonbounded} \wedge \langle \textsc{duration} \rangle \mathit{one\text{-}hour} \wedge [\mathit{segment\text{-}of}^{-1}]P$$

However, we do not introduce the inversion operator to our logic in this paper. Moreover, this transformation cannot be systematized as it would, for instance, break the compositionality for sentences with multiple quantifiers (Kallmeyer et al. 2015).

By means of (14), it follows that in the example under discussion, the whole one-hour event is of type *swimming*. We will see in the next section that this is different for iterations.

The substitution and adjunction in figure 6 trigger the unifications $\boxed{0} = \boxed{3}, \boxed{2} = i, \boxed{6} = l_2$ on the interface features. As a result, when applying these and collecting the formulas, we obtain the following underspecified semantic formulas:

(15) $@_i person \wedge \langle \textsc{name} \rangle Peter,$
$l_1 : \exists \boxed{3}, l_2 : swimming \wedge \langle \textsc{agent} \rangle i,$
$l_4 : \downarrow e.nonbounded \wedge \langle \textsc{duration} \rangle one\text{-}hour$
$\wedge \forall(\langle segment\text{-}of \rangle e \rightarrow l_2),$
$\boxed{3} \lhd^* l_4, \boxed{3} \lhd^* l_2$

The only possible disambiguation mapping is $\boxed{3} \mapsto l_4$, which yields, with an additional conjunctive interpretation of the set, the formula (16):

(16) $@_i person \wedge \langle \textsc{name} \rangle Peter$
$\wedge \exists \downarrow e.(nonbounded \wedge \langle \textsc{duration} \rangle one\text{-}hour$
$\wedge \forall(\langle segment\text{-}of \rangle e \rightarrow swimming \wedge \langle \textsc{agent} \rangle i))$

Furthermore, given (14), $swimming \wedge \langle \textsc{agent} \rangle i$ also holds at e.

4.2 Punctual Events and *for*-Adverbials

Now we consider cases where a *for*-adverbial combines with a punctual event description. In this case, the event is reinterpreted as an iteration.

(17) Peter knocked at the door for ten minutes.

The meaning of (17) is that we have an iteration of knocking events, each of them involving Peter as an agent and the same door as a patient, and that the entire iteration goes on for ten minutes:

(18) $\exists(\downarrow e.iteration \wedge \langle \textsc{duration} \rangle ten\text{-}minutes \wedge \langle \textsc{agent} \rangle i \wedge \langle \textsc{patient} \rangle j$
$\wedge \forall(\langle segment\text{-}of \rangle e \rightarrow knocking \wedge \langle \textsc{agent} \rangle i \wedge \langle \textsc{patient} \rangle j))$
$\wedge @_i(person \wedge \langle \textsc{name} \rangle Peter) \wedge @_j door$

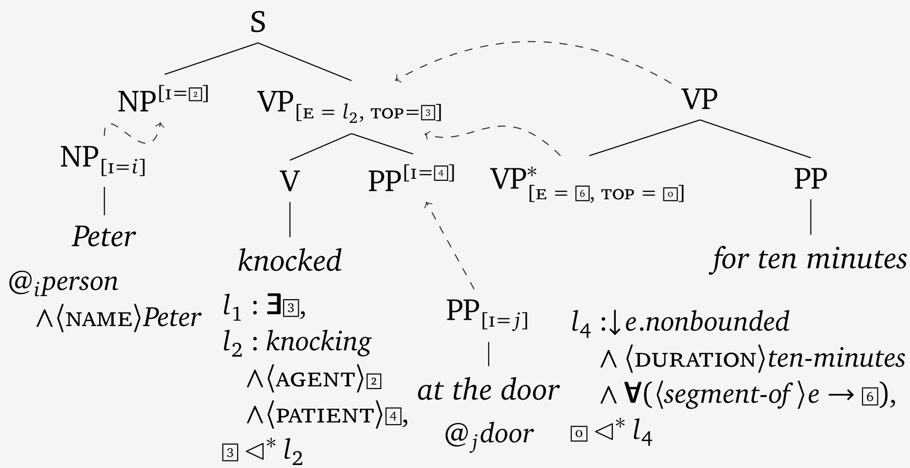

Figure 7 Derivation for (17)

Formula (18), however, leaves several aspects of iterations implicit. Firstly, we need to exclude the possibility that an iteration has no or only one segment. For this reason, following Dölling (2014), we assume that iterations consist of at least two segments:

(19) $$\forall(\downarrow e.\mathit{iteration} \rightarrow \exists(\downarrow e_1.\langle \mathit{segment\text{-}of} \rangle e \wedge \exists(\downarrow e_2.\langle \mathit{segment\text{-}of} \rangle e \wedge \neg @_{e_1} e_2)))$$

Besides this, the single segments must be distributed over the entire iteration in some regular way. We assume that the specification of what, for a specific type of iteration, "on a regular basis" means, is contextually given. We will not spell this out in this paper. Note that we do not require the segments of an iteration to be adjacent (in contrast to Dölling 2014). Typically, there are temporal gaps between the segments of an iteration. In particular, events of type *progression* and *iteration* are subject to different constraints on how their segments are related to each other.

Iterations, like progressions, are conceived of as nonbounded events and, hence, they satisfy the selectional restrictions of *for*-adverbials; recall (13). Furthermore, the following constraints make sure that every event of type *nonbounded* is either an *iteration* or a *progression* and that it cannot be both at the same time:

(20) $\forall(\mathit{nonbounded} \leftrightarrow \mathit{iteration} \vee \mathit{progression})$
$\forall(\mathit{iteration} \rightarrow \neg\mathit{progression})$

The derivation of (17) shown in figure 7 yields (21).

(21) $\exists\boxed{3}, l_2 : \mathit{knocking} \wedge \langle\textsc{agent}\rangle i \wedge \langle\textsc{patient}\rangle j,$
$l_4 : \downarrow e.\mathit{nonbounded} \wedge \langle\textsc{duration}\rangle \mathit{ten\text{-}minutes}$
$\wedge \forall(\langle \mathit{segment\text{-}of} \rangle e \rightarrow l_2),$
$@_i(\mathit{person} \wedge \langle\textsc{name}\rangle \mathit{Peter}), @_j \mathit{door},$
$\boxed{3} \lhd^* l_2, \boxed{3} \lhd^* l_4$

The only possible mapping is $\boxed{3} \mapsto l_4$, which leads, with a conjunctive interpretation of the resulting set, to (22).

(22) $\exists(\downarrow e.\mathit{nonbounded} \wedge \langle\textsc{duration}\rangle \mathit{ten\text{-}minutes}$
$\wedge \forall(\langle \mathit{segment\text{-}of} \rangle e \rightarrow \mathit{knocking} \wedge \langle\textsc{agent}\rangle i \wedge \langle\textsc{patient}\rangle j))$
$\wedge @_i(\mathit{person} \wedge \langle\textsc{name}\rangle \mathit{Peter}) \wedge @_j \mathit{door}$

We further adopt additional constraints on iterations and progressions concerning the possible types of their segments:

(23) $\forall(\langle \mathit{segment\text{-}of} \rangle \mathit{iteration} \rightarrow \mathit{bounded})$
$\forall(\mathit{punctual} \rightarrow \mathit{bounded})$
$\forall(\langle \mathit{segment\text{-}of} \rangle \mathit{progression} \rightarrow \mathit{nonbounded})$
$\forall(\mathit{nonbounded} \rightarrow \neg\mathit{bounded})$

Moreover, we have $\forall(\mathit{knocking} \rightarrow \mathit{punctual})$. With these constraints, e in (22) is necessarily of type *iteration* since its segments are of type *knocking*.

The given analysis does not make use of an explicit iteration operator, which is in line with Dölling 2014 and Deo & Piñango 2011 but in contrast to Champollion 2013 (see section 1). In the derivation shown in figure 7, the nonbounded event introduced by the *for*-adverbial is identified as being of type *iteration* based on the event type of the modified VP and the constraints listed in (20) and (23). Events of type *iteration* are subject to specific constraints on their inner structure, among which is the constraint stated in (19).

4.3 Bounded Events and *for*-Adverbials

More interesting though similar cases of bounded events that are iterated are, for example, (24).

(24) John biked to the office for three months.

Processing such examples seems to be more difficult than processing sentences as (17). As for the way the *for*-adverbial combines with the *John biked to the office* event, we keep the analysis from section 4.2: *John biked to the office* is a bounded event and, when embedded under the *for*-adverbial, it is extended to an iteration.

The crucial difference from *knock* in (17) is that the verb *bike* itself does not describe a bounded event. *Bike* without any additional goal specification is an event of type *progression*. The event boundary in (24) comes from the additional information provided by the PP *to the office*. This PP specifies the end of the path of the described movement and thereby delimits the event.

We now no longer want the type *progression* to be automatically inferred for all motion events of type *swimming* or *biking*. Instead, such motion events can become bounded if a goal is added, as formalized by the following constraints:

(25) $\forall(\mathit{biking} \rightarrow \mathit{motion})$
$\forall(\mathit{motion} \wedge \langle\textsc{goal}\rangle\top \rightarrow \mathit{bounded})$
$\forall(\mathit{motion} \wedge \langle\textsc{path}\rangle\top \rightarrow \mathit{directed\text{-}motion})$
$\forall(\mathit{directed\text{-}motion} \wedge \neg\langle\textsc{path}\rangle\langle\textsc{endp}\rangle\top \rightarrow \mathit{nonbounded})$
$\forall(\mathit{directed\text{-}motion} \wedge \mathit{nonbounded} \rightarrow \mathit{progression})$

The analysis of (24) in figure 8 is similar to the directed motion analyses proposed in Kallmeyer & Osswald 2013. The elementary tree used for *biked* in this analysis is the specific tree for the directed motion construction where a directional PP contributes the goal of the movement. In addition to contributing the goal, the PP also specifies some properties of the path, namely that its endpoint lies in the AT-REGION of the office. Given (25), the event of type *biking* in (24) is also of type *bounded* and consequently, the application of the *for*-adverbial triggers the creation of a node of type

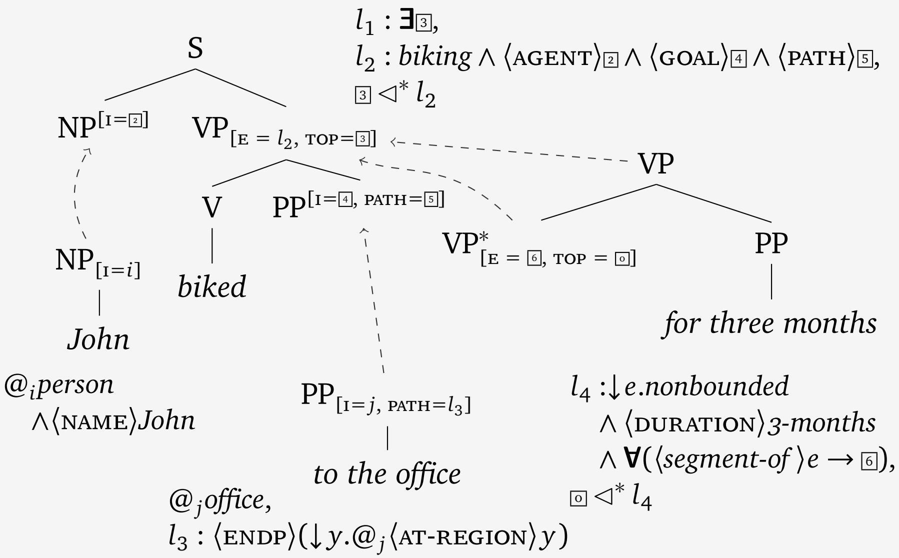

Figure 8 Derivation for (24)

iteration.

The underspecified semantic representation we obtain with the derivation in Fig. 8 is given in (26):

(26) $@_i person \wedge \langle\textsc{name}\rangle John,\ @_j office,$

$l_1 : \exists\boxed{3},$

$l_2 : biking \wedge \langle\textsc{agent}\rangle i \wedge \langle\textsc{goal}\rangle j \wedge \langle\textsc{path}\rangle l_3,$

$l_3 : \langle\textsc{endp}\rangle(\downarrow y.@_j\langle\textsc{at-region}\rangle y)$

$l_4 :\downarrow e.nonbounded \wedge \langle\textsc{duration}\rangle 3\text{-}months$

$\wedge\ \forall(\langle segment\text{-}of\rangle e \rightarrow l_2),$

$\boxed{3} \lhd^* l_2,\ \boxed{3} \lhd^* l_4$

The only possible disambiguation is $\boxed{3} \mapsto l_4$, which yields, under a conjunctive interpretation, to (27):

(27) $@_i person \wedge \langle \textsc{name} \rangle John \wedge @_j office,$
$\wedge \exists \downarrow e.nonbounded \wedge \langle \textsc{duration} \rangle 3\text{-}months$
$\wedge \forall (\langle segment\text{-}of \rangle e \rightarrow biking \wedge \langle \textsc{agent} \rangle i \wedge \langle \textsc{goal} \rangle j$
$\wedge \langle \textsc{path} \rangle \langle \textsc{endp} \rangle (\downarrow y.@_j \langle \textsc{at-region} \rangle y))$

Due to the existence of the GOAL and the PATH, we can infer that the *biking* events are in this case *bounded directed-motion* events. Consequently the entire event has to be an *iteration*.

4.4 Interaction with the Scope of Indefinites

As mentioned in section 1.1, indefinites usually do not take narrow scope with respect to a *for*-adverbial in the way they can have different scope with respect to other adverbials or quantifiers. In the examples in (28) (from Kratzer 2007), the indefinite always scopes over the adverbial.

(28) a. John pushed a cart for an hour.
b. I dialed a wrong phone number for five minutes.
c. She bounced a ball for 20 minutes.

The following example (taken from Zucchi & White 2001) shows that in cases where a narrow scope reading would be preferred for plausibility reasons, it is nevertheless not possible if no clue is available from context or world knowledge of how to partition the interval:

(29) ??John found a flea on his dog for a month.

Before discussing our analysis, let us have a look at the proposal in Champollion 2013.

(30) John dialed a wrong phone number for five minutes.

For (30), Champollion proposes the representation in (31).

(31) $\lambda I[\exists e \exists x[number(x) \wedge {}^*dial(e, john, x) \wedge I = \tau(e)$
$\wedge\, minutes(I) = 5 \wedge \forall J[J \in \mathscr{R}_I^{short(I)}$
$\rightarrow \exists e' \exists y[number(y) \wedge {}^*dial(e, john, y) \wedge J = \tau(e')]]]]$

The existential $\exists x$ is taken to be part of the P predicate in the semantics

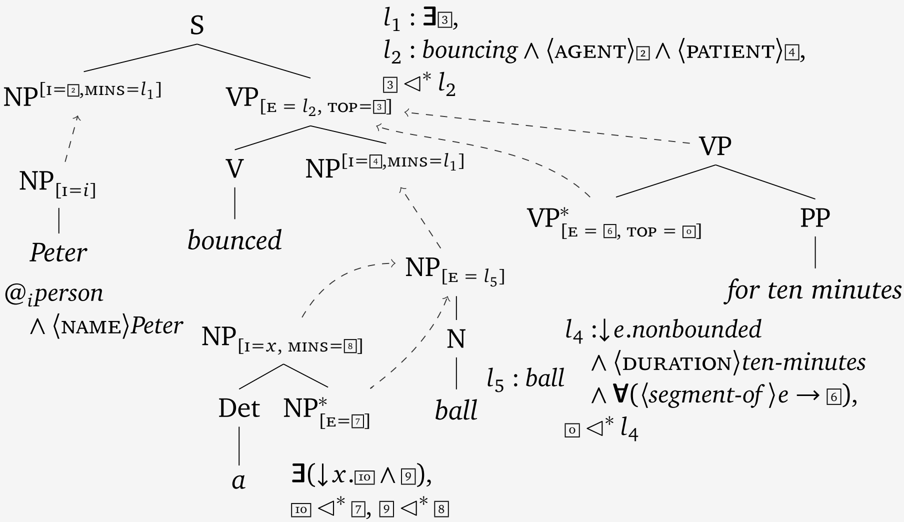

Figure 9 Derivation for (32)

of the *for*-adverbial. Since one part of the *for*-semantics requires P to hold at the entire interval I, one correctly obtains that there is a single phone number $number_I$ that has been dialed repeatedly over the interval I. However, in the predicates that apply to the smaller time intervals J, there is also an existential quantification $\exists y$ over phone numbers and the dialing here applies to y, not to x. In other words, in every shorter interval J, there has been a repeated dialing of some number $number_J$ that is possibly different from $number_I$. This is at least unnecessary and goes against what the meaning of *for*-adverbials is supposed to capture, namely that the same number has been dialed in each of these smaller time intervals. But without any additional postulate, (31) does not prevent there to be intervals among the J during which there was no dialing of $number_I$.

Our analysis avoids the second existential quantification in the scope of the universal quantification coming from the *for*-adverbial. Therefore, each subevent involves the same x as the entire event. Let us explain our analysis with the example (32).

(32) Peter bounced a ball for ten minutes.

In the analysis of quantifiers in figure 5, the quantifier gets its minimal scope from some interface feature MINS. According to figure 5, the value of this feature is the label of the ∃ formula associated with the verbal predicate. If this is adapted to (32), the prediction is that indefinites have scope over the *for*-adverbial.

The derivation of (32) is given in figure 9. The label l_1 of the ∃ formula introducing the event node is passed to the quantifier as its minimal scope via the interface feature MINS. Due to the unification of interface variables during substitution and adjunction and due to the final top-bottom unification, we obtain the result that $\boxed{8}$ (the minimal scope of the indefinite) gets identified with l_1 while the *for*-adverbial gets embedded under $\boxed{3}$, which is the scope of the ∃-formula labeled l_1. In other words, the predicate *bounce* contributes two scope windows: a scope window for quantifiers with a lower limit given by the MINS feature and a lower scope window inside the event structure, delimited by the TOP feature and the E value. *For*-adverbials target this lower scope window since they modify the internal structure of the event.

As a result, we obtain the underspecified HL formula in (33):

(33) $@_i person \wedge \langle\textsc{name}\rangle Peter,$
$l_1 : \exists\boxed{3},\ l_2 : bouncing \wedge \langle\textsc{agent}\rangle i \wedge \langle\textsc{patient}\rangle x,$
$\exists(\downarrow x.\boxed{10} \wedge \boxed{9}), l_5 : ball,$
$l_4 : \downarrow e.nonbounded \wedge \langle\textsc{duration}\rangle ten\text{-}minutes$
$\wedge \forall(\langle segment\text{-}of\rangle e \rightarrow l_2),$
$\boxed{3} \lhd^* l_4, \boxed{10} \lhd^* l_5, \boxed{9} \lhd^* l_1, \boxed{3} \lhd^* l_2$

The only possible disambiguation, $\boxed{10} \mapsto l_5$, $\boxed{9} \mapsto l_1$, $\boxed{3} \mapsto l_4$, yields (34):

(34) $@_i person \wedge \langle\textsc{name}\rangle Peter$
$\wedge \exists(\downarrow x.ball \wedge \exists \downarrow e.nonbounded \wedge \langle\textsc{duration}\rangle ten\text{-}minutes$
$\wedge \forall(\langle segment\text{-}of\rangle e \rightarrow bouncing \wedge \langle\textsc{agent}\rangle i \wedge \langle\textsc{patient}\rangle x))$

This analysis correctly predicts that a quantifier can have narrow scope with respect to a second quantifier since both target the same scope window. However, they both have to scope over a *for*-adverbial.

(35) Every boy bounced a ball for ten minutes.

For (35), in our analysis, we obtain the underspecified formula in (36).

(36) $l_1 : \exists\boxed{3}, l_2 : bouncing \wedge \langle\textsc{agent}\rangle x \wedge \langle\textsc{patient}\rangle y,$
$\forall(\downarrow x.\boxed{10} \rightarrow \boxed{9}), l_5 : boy, \exists(\downarrow y.\boxed{11} \wedge \boxed{12}), l_6 : ball,$
$l_4 : \downarrow e.nonbounded \wedge \langle\textsc{duration}\rangle ten\text{-}minutes$
$\wedge \forall(\langle segment\text{-}of\,\rangle e \rightarrow l_2),$
$\boxed{3} \lhd^* l_4, \boxed{10} \lhd^* l_5, \boxed{9} \lhd^* l_1, \boxed{11} \lhd^* l_6, \boxed{12} \lhd^* l_1, \boxed{3} \lhd^* l_2$

The dominance constraints from (36) are depicted in figure 10. Here, we can see clearly that the scope window for the two quantifiers where the scope order of the universal and the existential is underspecified is higher than the universal quantification coming from the *for*-adverbial.

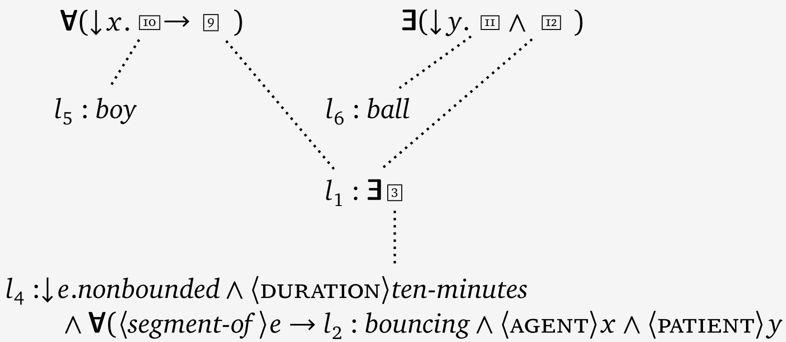

Figure 10 Dominance constraints from (36)

5 Conclusion

The frame-semantic perspective supports a fine-grained and structured characterization of semantic components. By using Hybrid Logic as a description language, we added quantification to frame semantics while preserving the original object-centered view. We applied this formalism to the analysis of *for*-adverbials and their interaction with the aspectual properties of the modified verb phrases. Moreover, by allowing underspecified formulas, we integrated our analysis into a fully compositional model of the syntax-semantics interface within the LTAG framework.

In the proposed model, the semantic representation of *for*-adverbials selects for nonbounded events and comes with a universal quantification over event components. Based on the event type of the modified VP and general semantic constraints on the types of events and their event components, the correct type of the overall phrase (i.e., iteration vs. progression) can be inferred without assuming an additional iteration operator or the like. Finally, we have shown how our model can cope with the specific scopal behavior that *for*-adverbials show with respective to indefinites.

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Domain-specific and General Syntax and Semantics in the Talkamatic Dialogue Manager

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Abstract We present a design philosophy for dialogue system development, where domain-specific domain knowledge is clearly separated from the logic for generic dialogue capabilities. We hope that this provides a useful illustration of how one may approach the division of labour between general and domain-specific syntax, semantics and pragmatics.

Keywords dialogue · dialogue systems · syntax · semantics · dialogue management · grammar

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1 Introduction

This paper outlines a format, currently under development, for specifying *Dialogue Domain Descriptions* (DDD) for a domain-independent dialogue system, the Talkamatic Dialogue Manager (Larsson et al. 2011a,b). One of the central principles underlying the design of TDM is the separation of domain-specific knowledge from general dialogue capabilities. We hope that this provides a useful illustration of how one may approach the division of labour between general and domain-specific syntax, semantics and pragmatics in a dialogue system.

These practical considerations may also be of interest from a more theoretical perspective. One may conjecture that general principles that provide the basis for a useful dialogue systems design also says something about the nature of the human ability to participate in natural language dialogue. Exactly how to pin down the relation between dialogue systems and human linguistic competence, however, is a delicate matter. It is important to be aware that the usefulness of some design principles may be due to the needs of dialogue application designer in being able to quickly construct (and debug) dialogue system applications, something which has no counterpart with regard to human linguistic competence.

2 The Talkamatic Dialogue Manager

The Talkamatic Dialogue Manager (TDM) is a commercial platform for building spoken dialogue systems. It is a reimplementation and development of the GoDiS/IBiS (Gothenburg Dialogue System/Issue-Based Information System) system described in Larsson 2002, developed using the information state update approach to dialogue management (Traum & Larsson 2003), which takes considerable input from the KoS (conversation-oriented semantics) framework (Ginzburg 2012).

TDM consists of the following runtime subcomponents:

- Frontend: mainly consisting of an automatic speech recogniser and a text-to-speech synthesiser.
- Backend: consisting of a dialogue move engine, natural-language interpreter, etc.
- Session Manager: providing each frontend with access to a backend, and routing communication between frontend and backend.

TDM also contains design-time subcomponents constituting an SDK (software development kit) for developing DDDs. Dialogue domains consist of the following parts:

- An ontology defining concepts, entities and actions that the user and the system may reference in questions, answers and requests.
- Domain knowledge in the form of dialogue plans (and related notions), describing how actions are carried out and how questions are answered. Plans also describe what information is needed in order to carry out the actions or to answer the questions.
- A language model or grammar, describing words and utterances used by the user and system. In other words, the language model defines syntax rules and mappings between linguistic surface forms and semantic entities.
- A service interface describing how services that the domain depends on are accessed and used, for example web APIs or functionality

hosted natively on the user's device.

3 Dialogue Design

TDM is the result of an effort to build a dialogue manager on sound engineering principles, exploiting knowledge from research about human dialogue. The following principles have guided TDM design:

- Apply general solutions to general problems
- Don't mix different kinds of knowledge

These principles have led to an architecture where knowledge about the domain (e.g., telephony or navigation) is separated from general knowledge about dialogue. This means that app developers can focus on defining domain-specific knowledge, such as information about concepts and which words are used to talk about the concepts. General dialogue capabilities such as asking questions, giving answers and providing feedback are built into the dialogue manager and do not need to be provided by app developers. This facilitates building apps since general dialogue strategies need not be reinvented each time a new dialogue is built. Thus, the developer can focus on app-specific development.

For example, one can consider a simple app enabling the user to make phone calls. The developer specifies that calling contacts is an action which requires the system to know who to call. The developer also specifies that the system asks about this information with the sentence "Who do you want to call?" Based on this domain knowledge, TDM will choose to ask the question "Who do you want to call?" whenever the information is required. It may also choose to repeat the question when motivated, or to refrain from asking the question if the answer has been provided without prompting the user. In other words, the overall logic governing the dialogue is contained within TDM, while domain-specific knowledge, such as dependencies between various kinds of information in the form of dialogue plans, are kept in the DDDs.

The same principle of division of labour holds for the surface forms of user and system utterances. General forms for dialogue moves are specified in a domain-independent grammar, which is then fleshed out by a domain-specific grammar which supplies the surface forms associated with domain-specific entities, predicates and actions.

When an app developer builds a new app, there is no need to extend or modify the dialogue manager as such – only domain-specific knowledge needs to be supplied. The idea is that since dialogue design is built into the TDM, it should be easy to produce usable, well-designed dialogue interfaces. Natural and flexible dialogue flow is a built-in feature which comes for free when specifying the dialogue plans. The built-in feedback model ensures that user and system are on the same track. A rich contextual model is available for intelligent interpretation of speech recognition results, as well as providing information for disambiguation of unclear utterances. Additionally, language models (grammars) are described at a high level of abstraction in a simple format, which makes it easier for non-linguists to build and localise apps.

However, it is important to note that TDM cannot participate in arbitrarily complex dialogue. Roughly, TDM covers dialogues requiring the system to provide some information to a user or to perform some action, and to do this, the system needs to collect certain bits of information from the user. Information search can be incremental in that a range of options is manipulated in successive steps until one option is chosen by the user. For example, if the user asks the system to play a radio program, the system will ask the user to specify parameters such as genre (music, news, sports, etc.) and channel (in Swedish radio: P1, P2, P3, local channels, etc.). Whenever the user specifies or modifies a parameter, the range of options listed changes. When the user finally selects one of the options, the program starts playing. During the interaction, the user can behave fairly freely, and for example switch to other conversational topics and return to the radio program topic without the system losing context. However, TDM is currently *not* designed to handle, for example, complex planning tasks where several plans to achieve a goal are compared and argued for and against. Nor can it handle purely socially oriented dialogue that has no concrete task other than maintaining social relations.

TDM's built-in dialogue design enables more complex interactions than most other dialogue managers on the market, while keeping a fairly simple dialogue design format. The subsequent subsections describe some of the general dialogue features in more detail.

3.1 Flexible Dialogue Flow

Given a simple dialogue plan specifying a default dialogue flow which achieves a given goal, TDM manages a wide variety of dialogue flows to achieve the goal. If the user simply responds to system questions, the dialogue will follow the default flow. But if the user chooses to give more or other information than requested, or takes initiative to talk about something else, TDM adapts to this. The user may even just provide some information which is relevant to him or her at the moment, and TDM will either figure out what the user wants to do, or ask a clarification question to move the dialogue along. It is also possible to revise answers without having to restart the dialogue.

Some aspects of flexible dialogue flow are present in systems like Siri and Google Now, and some are supported by the VoiceXML standard. However, compared to most other systems TDM offers a relatively wide and complete range of flexible dialogue behaviours. To take one example, if the user changes the subject while talking to Siri, the previous topic will be forgotten by the system. In contrast, once the embedded topic has been finished, TDM will switch back to the previous topic and signal this explicitly. This means that if the user asks, for example, about the weather while checking bus routes to a specific destination, TDM provides the weather information and then returns to the previous activity by saying “Returning to selecting a route.” The surface form for such dialogue moves, which indicate *sequencing*, are defined in the domain-independent grammar component.

3.2 Feedback

TDM features a fairly elaborate feedback model to cope with communication problems. Feedback (positive and negative) and clarification questions are given on several levels. For example, assuming that a user said “Anna” to a telephony app, the system could give feedback regarding perception (“I didn’t hear anything from you,” “I heard you say Anna, is that correct?”), semantics (“I don’t understand,” “OK, Anna”), intentions (“OK, you said Anna. Do you want to make a call?”) and acceptance/rejection (“I don’t have a phone number for Anna”). All feedback utterances are defined in a domain-independent grammar component.

Pinpointing communication errors and clarifying potential misunderstandings means better chance of dialogue success. However, excessive feedback may lead to inefficient dialogues and dissatisfied users, which is why speech recognition and interpretation leads to various contextual factors. These contextual factors in turn may be helpful in perceiving and understanding user utterances.

4 Dialogue Domain Descriptions

This section gives a brief overview of the XML format for DDDs. The format supports ontology, plans, grammar and interaction tests. The last part (service interface) will be addressed in future work. Note that this section is not intended as a manual for building DDDs, and only provides a partial description of the DDD XML format. Code excerpts are taken from the Talkamatic GitHub repository, where the complete example DDD can be found.[1]

4.1 Ontology and Semantics

Ontology works as a TDM's table of all entities and actions that a specific application talks about. The following kinds of entities are defined by the ontology, also described by the example in figure 1.

- *Sorts* (general or domain-specific) ontological categories which are used to enforce sortal constraints on semantic representations, and to guide interpretation and generation.
- *Individuals* which include all single entities that the app can talk about (e.g., contacts). Individuals can be declared explicitly in the ontology. For example, in the phone domain an individual `Anna` can be declared to be of the sort `contact`. Alternatively, a sort can be declared as `dynamic`, which means individuals of that sort are created dynamically in runtime by consulting the service interface.
- *Predicates* are used for representing propositions and questions (represented in XML using only predicates). Each (one-place) predicate declares the required sort of its argument (or value). For example, the argument of the `contact_to_call` predicate can only be a `contact`, thus `Anna` will be a valid argument.

[1] See the site `https://github.com/Talkamatic/dialogue-domain-descriptions/tree/master/android/android`.

```xml
<ontology name="PhoneOntology">

  <action name="call"/>

  <sort name="contact" dynamic="true"/>
  <sort name="phone_number" dynamic="true"/>

  <predicate name="phone_number_of_contact" sort="phone_number"/>
  <predicate name="selected_contact_to_call" sort="contact"/>
  <predicate name="selected_contact_of_phone_number" sort="contact"/>

</ontology>
```

Figure 1 Ontology for the phone domain

- *Actions* that TDM can be requested to carry out, typically by calling the service interface.

The elements defined in the ontology are used in domain-specific semantic representations in TDM. The account in Larsson 2002 uses a very simple representation of propositions loosely based on predicate logic (without quantification). This is extended this with lambda-abstraction of propositions and a question operator "?" which can be thought of as a function from a (possibly lambda-abstracted) proposition to a question. Furthermore, Larsson (2002) uses a (domain-independent) semantic category to account for the content of short answers (e.g., "yes" or "Paris"). This representation is also the basis for the semantic representations currently used in TDM.

Propositions correspond roughly to basic formulae of predicate logic consisting of an 0-ary or 1-ary predicate together with constants representing its arguments, for example **return-trip** (0-ary predicate) and **dest-city(paris)** (using an 1-ary predicate).

- $Expr$: Proposition if
  - $Expr$: Pred_0 or
  - $Expr = pred_1(arg)$, where arg : Ind and $pred_1$: Pred_1 or
  - $Expr = \neg P$, where P : Proposition

In a dialogue system operating in a domain of limited size, it is often not necessary to keep a full semantic representation of utterances. For example, a user utterance of "I want to go to Paris" could be represented semantically as, for example, **want(user, go-to(user, paris))** or **want(u, go-to(u,p)) & city(p) & name(p, paris) & user(u)**. TDM uses a reduced semantic representation with a coarser, domain-dependent level of granularity; for example, the above example will be rendered as **dest-city(paris)**. This reduced representation reflects the level of semantic granularity inherent in the underlying domain task. As an example, in a travel agency domain there is no point in representing the fact that it is the user (or customer) rather than the system (or clerk) who is going to Paris; it is implicitly assumed that this is always the case.

As a consequence of using reduced semantics, it will be useful to allow 0-ary predicates, for example **return-trip** meaning "the user wants a return ticket". Furthermore, so far we have not found reason to move beyond unary (1-place) predicates in TDM. We conjecture that this is due to the structure of the kind of dialogue that TDM can currently engage in, where propositions are essentially equivalent to feature-value pairs. An interesting question is how far one can get with one-place predicates, and when this breaks down. One hypothesis is that binary predicates will be needed as soon as there is a need to talk about several entitities of the same kind (flights, for example), which have different properties (e.g., travel time, number of stops, price, etc.). This happens, for example, in negotiative dialogue of the sort described in Larsson 2002.

The advantage of the semantic representation used in TDM is that the specification of domain-specific semantics becomes simpler, and that unnecessary "semantic clutter" is avoided. However, it does have limited expressive power and would need to be extended to deal with more complex genres of dialogue requiring a more fine-grained semantics, for example by adding binary and perhaps n-ary ($n > 2$) predicates.

Three sorts of questions are treated by TDM: *y/n*-questions, *wh*-questions, and alternative questions.

- Expr : Question if Expr : YNQ or Expr : WHQ or Expr : ALTQ
- $?P$: YNQ if P : Proposition
- $\mathbf{?}x.\mathit{pred}_1(x)$: WHQ if x : Var and pred_1 : Pred_1
- $\mathbf{\{}?\mathit{ynq}_1, \ldots, ?\mathit{ynq}_n\mathbf{\}}$: ALTQ if ynq_i : YNQ for all i such that $1 \leq i \leq n$

In TDM semantics, *y/n*-questions correspond to propositions preceded by a question mark, for example **?dest-city(london)** ("Do you want to go to London?"). *Wh*-questions correspond to lambda-abstracts of propositions, with the lambda replaced by a question mark, for example **?x.dest-city(x)** ("Where do you want to go?"), and alternative questions are sets of *y/n*-questions, for example **{?dest-city(london), ?dest-city(paris)}** ("Do you want to go to London or do you want to go to Paris?"). Here, TDM semantics goes beyond standard predicate logic. Note, by the way, that we do not provide a model theoretic semantics for this notation. While this would be fairly straightforward (possibly with some minor complications related to the semantics of questions), we see no clear role for such a semantics in a dialogue system, except possibly as a tool for ensuring consistency and orderliness. The use of the term "semantics" for these representations is motivated, rather, from their role in providing a structure for the domain which is used for mediating between natural language utterances (from both user and system) and the underlying service interface.

Ginzburg uses the term "short answers" for phrasal utterances in dialogue such as "Paris" as an answer to "Where do you want to travel?" in a travel agency setting. These are standardly referred to as *elliptical* utterances. Ginzburg argues that (syntactic) ellipsis, as it appears in short answers, is best viewed as a semantic phenomenon with certain syntactic presuppositions. That is, the syntax provides conditions on what counts as a short answer but the processing of short answers is an issue for semantics.

We follow this in seeing short answers from a semantic point of view. What this means, in effect, is that we are not interested in syntactic ellipsis, but rather in semantic underspecification of a certain kind. Furthermore, the semantics used by the system is domain-dependent and thus what we are really interested in is semantic underspecification *with regard to the domain/activity*. On this account, an utterance is semantically underspecified iff it does not determine a unique and complete proposition in the given activity. Of course, this means that whether an utterance is regarded as underspecified or not depends on the granularity of propositional content, and what types of entities are interesting in a certain activity. For example, given the type of simple semantics that we are using on our sample travel agency domain, "to Paris" is not semantically elliptical, since it determines the complete proposition **dest-city(paris)**. However, "to Paris" would be semantically underspecified in an activity where it could also be taken to mean for example "You should go to Paris."

- *Expr* : ShortAns if
  - *Expr* = **yes** or
  - *Expr* = **no** or
  - *Expr* : Ind or
  - *Expr* = $\neg arg$ where *arg* : Ind

In general, semantic objects of type ShortAns can be seen as underspecified propositions. In TDM, we only deal with individual constants (i.e., members of Ind), and answers to *y/n*-questions, i.e., **yes** and **no**. Individual constants can be combined with *wh*-questions to form propositions, and **yes** and **no** can be combined with *y/n*-questions.

Note that we allow expressions of the form ¬arg where *arg*:Ind as short answers. This is used for representing the semantics of phrases like "not Paris." In a more developed semantic representation these expressions could be replaced by a type-raised expression, for example $\lambda P.\neg P(arg)$.

Questions and answers can be combined to form propositions, as shown in table 1. The special case for *wh*-questions is similar to functional application, as when the question **?***x***.dest-city(***x***)** is combined with **paris** to form **dest-city(paris)**. Questions can also be combined with propositions, yielding the same propositions as result provided the question and the propositions have the same predicate and that the proposition is sortally correct. It is also possible to combine *y/n*-questions and alternative questions with answers to form propositions. In general, we say that a question *q* and an answer *a combine* to form a proposition *p*. Related definitions of answers being *relevant* to and *resolving* questions are given in Larsson 2002.

4.2 Dialogue Plans

Plans include information about how the dialogue with the user should progress. Figure 2 shows an example. TDM requires a top plan (`action = "top"`) declaring what the system should at the outset of each interaction. In general, plans are identified by their goals, that is, things that the plan shall have done by its completion. There are two types of goals in TDM:

Question	Answer	Proposition
$?x.pred_1(x)$	a or $pred_1(a)$ $\neg a$ or $\neg pred_1(a)$	$pred_1(a)$ $\neg pred_1(a)$
$?P$	**yes** or P **no** or $\neg P$	P $\neg P$
$\{?P_1, ?P_2, \ldots, ?P_n\}$	$P_i, (1 \leq i \leq n)$ $\neg P_i, (1 \leq i \leq n)$	P_i $\neg P_i$

Table 1 Combining questions and answers into propositions

resolving a question, and performing an action. These are represented as follows (the corresponding XML representations can be seen in figure 2):

- **resolve(**q**)** where q:Question
- **perform(**α**)** where α:Action

A plan tag includes a goal and all the steps that are needed to be done to accomplish the goal. Such a step can be the `findout(`q`)` item which tells TDM that the question q needs to be resolved. For example, within the `call` goal, the `findout` statement instructs TDM to resolve a wh-question formed by the `selected_contact_to_call` predicate). A `dev_perform` item signifies that TDM has to execute an action external to the dialogue, for example making a call, sending an SMS or updating a database. The execution of external actions is specified in the service interface. Similarly, `dev_query` is like `dev_perform` except that it specifies a question, prompting TDM to await an answer to the question to be returned from the service interface.[2]

4.3 Grammar

TDM takes hybrid template/grammar approach to natural language generation and interpretation, where grammatical knowledge is used to minimize the work involved in developing and localising an application to a new language. Domain-specific linguistic knowledge, defined by the app

[2]The TDM service interface definition is currently being converted into XML format, and we will not describe it further here. Suffice to say that the service interface needs to define all the queries and actions (defined using `dev_query` and `dev_perform`) that are included in the dialogue plans, as well as some related knowledge.

```
<domain name="PhoneDomain" is_super_domain="true">

 <goal type="perform" action="top">
  <plan>
   <forget_all/>
   <findout type="goal"/>
  </plan>
 </goal>

 <goal type="perform" action="call">
  <plan>
   <findout type="wh_question" predicate="selected_contact_to_call"/>
   <dev_perform action="Call" device="AndroidDevice" postconfirm="true"/>
  </plan>
  <postcond><device_activity_terminated action="Call"/></postcond>
 </goal>

 <goal type="resolve" question_type="wh_question" predicate="phone_number_of_contact">
  <plan>
   <findout type="wh_question" predicate="selected_contact_of_phone_number"/>
   <dev_query device="AndroidDevice" type="wh_question"
              predicate="phone_number_of_contact"/>
  </plan>
 </goal>

</domain>
```

Figure 2 Domain knowledge for phone domain (excerpt)

developer, is kept separate from other domain knowledge and from general linguistic knowledge built into TDM.

The grammar specifies a language model which consists of mappings between linguistic surface forms (primarily text strings) and semantic entities relating to the ontology, such as individuals, actions and questions. A single grammar specifies both user and system utterances, thus promoting consistency between what the system can say and what it can understand.

The grammar used by a TDM application is a combination of a domain-specific grammar (such as that shown in figure 3) and a general TDM grammar, which specifies the general form of the main TDM dialogue moves (`ask`, `answer`, `request`, `confirm` and `greet`) as well as for feedback moves. This means that the domain-specific grammar can be kept to a minimum.

The first entry in figure 3 (`action name="call"`) expresses that the action **call** can be referred with a verb phrase containing the verb *call*. It also contains a lexicon describing the grammar of call in English. We only

```
<grammar>

  <action name="call">
    <verb-phrase>
      <verb ref="call"/>
    </verb-phrase>
  </action>

  <lexicon>
    <verb id="call">
      <infinitive>call</infinitive>
    </verb>
  </lexicon>

  <request action="call">
    <utterance>
      <one-of>
        <item>make a call</item>
        <item>call <individual sort="contact"/></item>
      </one-of>
    </utterance>
  </request>

  <question speaker="system" predicate="selected_contact_to_call" type="wh_question">
    <utterance>who do you want to call</utterance>
  </question>

  <predicate name="phone_number_of_contact">
    <noun-phrase>
      <noun ref="number"/>
    </noun-phrase>
  </predicate>

  <question speaker="user" predicate="phone_number_of_contact">
    <utterance>
      <one-of>
        <item>tell me a phone number</item>
        <item>what is <individual sort="contact"/>'s number</item>
        <item>tell me <individual sort="contact"/>'s number</item>
      </one-of>
    </utterance>
  </question>

  <answer speaker="system" predicate="phone_number_of_contact">
    <utterance>
      <individual predicate="selected_contact_of_phone_number"/> has number
        <individual predicate="phone_number_of_contact"/>
    </utterance>
  </answer>

</grammar>
```

Figure 3 Grammar for the phone domain (excerpt) need to specify the infinitive form for the verb. The other forms, such as imperative and present progressive, are derived automatically from the general grammar resource for English.

The domain-general grammar also states that actions can be requested by using the imperative form that refers to the action, in this case "Call." When the system asks what the user wants to do, it may use the infinitive form, as in "Do you want to call?" The present progressive can be used by system confirmations, for example "Calling" or "Calling Anna."

Since these basic forms may not always be sufficient, additional forms can be declared in the domain-specific grammar. Multiple alternative forms can be provided using the `<one-of>` tag which encloses alternatives as `<item>`s. See the third entry in figure 3 for an example.

As can be seen by the second `item` in the third entry in figure 3, TDM grammar entries may use placeholders for individuals, represented by the `<individual>` tag. This tag specifies a predicate, which in generation is instantiated with the surface form of the individual that the predicate holds of. In interpretation, a slot is similarly expected to be instantiated with the surface form of the individual that the predicate holds of. The rest of the grammar excerpt in figure 3 declares how the system is to ask questions about who to call; how the user may ask for the phone number of a contact; and how the system may answer questions about phone numbers of a given contact.

Given a grammar such as that shown in figure 3 (extended with some additional surface forms for other actions), TDM can generate and understand a range of utterances combining elements from a domain-specific grammar (in dark green) and the domain-independent resource grammar provided by TDM (in blue):

- System alternative question: Do you want to make a call or get the number of a contact?
- System wh-question: Who do you want to call?
- System report: Calling; Calling Anna
- System feedback: I heard you say Anna, is that correct?; OK, Anna
- System topic management: Returning to calling
- User request: I want to make a call; Call Anna, I want to call Anna; Would you please call Anna

- User answers: Anna
- User feedback: Pardon?, Please repeat

Above, we have only shown excerpts from the English grammar. Complete English, French and Dutch grammars for the example domain are available from GitHub.[3]

5 Domain-independent Knowledge in TDM

Apart from the rules and algorithms governing dialogue management, which are general within the confines of the kind of action- and issue-oriented dialogue that TDM was designed for, domain-independent knowledge in TDM includes the following:

- The types of dialogue moves that speakers can perform, and the kinds of semantic entities they take as arguments (e.g., `ask` moves take questions)
- Information state update rules and algorithms governing dialogue management, including rules connecting dialogue moves to information state updates
- The format for sentence-level semantic entities such as propositions and questions, and their relation to the domain-specific predicates, entities and actions
- General and abstract semantic relations between questions and answers, such as whether an answer is *relevant* to, *resolves*, or *combines with* a question, defined in terms of semantics, and used to define update rules
- General surface forms and patterns which are used together with domain-specific grammars for parsing and generating utterances, thus connecting them to the TDM dialogue moves

In the information-state approach, the precise semantics of a dialogue move type is determined by the update rules which are used to integrate moves of that type into the information state. This means that all occurrences of a move type are integrated by the same set of rules. The update rules (and associated algorithms) used in the GoDiS/IBiS system,

[3] See the site `https://github.com/Talkamatic/dialogue-domain-descriptions/tree/master/android/android/grammar`.

and forming the starting point for the rules used in TDM, are descibed in Larsson 2002.

While dialogue move types are often defined in terms of sentence mood, speaker intentions, and/or discourse relations (Core & Allen 1997), we opt for a different solution. In our approach, the type of move realized by an utterance is determined by the relation between the content of the utterance, and the activity in which the utterance occurs. For example, if an utterance provides information which is relevant to a question in the domain, it is regarded as realizing an answer move (regardless of whether the question has been asked).

The following dialogue moves are used in TDM:

- ask(q), where q : Question
- answer(a), where a : ShortAns or a : Proposition
- request(α), where α : Action
- report(α, σ), where α : Action and σ : Status is the status of the action (one of **started**, **ended**, and **failed**)
- greet
- quit

In inquiry-oriented dialogue, the central dialogue moves concern raising and addressing issues. This is done by the ask and answer moves, respectively. For action-oriented dialogue, the request and report moves are added to enable requesting and reporting on the status of actions. The greet and quit moves are used in the beginning and end of dialogues to greet the user and indicate that the dialogue is over, respectively.

6 Semantic Coordination in Dialogue Systems

Cooper & Ranta (2008) propose a shift in perspective from the view of natural languages as formal languages to natural languages as a collection of resources for constructing local languages for use in particular situations. They point to a research programme investigating how such resources play a role in linguistic innovation by agents constructing situation-specific local languages and how they can be made dynamic, modified by the linguistic agent's exposure to innovative linguistic data. This is related to a prominent problem in current dialogue systems, namely, the fact that users are constrained to a static pre-programmed language – what Brennan (1998) refers to as the *vocabulary problem in spoken dialogue systems*.

Present-day dialogue systems require users to talk in ways foreseen by programmers. This makes systems less useful and may lead to increased cognitive load on user, making systems potentially dangerous to use, for example while driving. When exposed to unexpected formulations, language understanding in a dialogue system will break down. By contrast, when exposed to unexpected formulations, people are capable of *semantic coordination* (Larsson 2015), either by (silently) figuring out (based on linguistic and contextual clues) a plausible meaning and updating their own take on how language is used in the current context, or by interactive clarification and meaning negotiation.

Eventually, we will want to enable dialogue systems to handle semantic coordination, which requires the ability to adapt old meanings and learn new ones, and clarify and negotiate meanings in metalinguistic dialogue. The kind of semantics used in present-day dialogue systems capture only a fraction of the natural language meanings of the words in the grammar. A simple addition would be to allow adding new ways of referring to known individuals, predicates, etc. However, semantic coordination will be more useful when meaning representations have more structure and where more reasoning is performed.

In this context, a possible conjecture with respect to learning vs. programming of domain-dependent and domain-independent knowledge about syntax, semantics and pragmatics could be that only domain-specific knowledge need to be learnable, whereas domain-general knowledge can be preprogrammed. (Pre-programmed pragmatics will include strategies and dialogue acts for engaging in semantic coordination.) The intuition behind this conjecture is that while language is continually adapted by speakers to specific domains, the general linguistic resources that underpin this adaptation change at a pace that, for the purposes of dialogue systems development, can be handled on an engineering level without excessive cost. Further support can perhaps be found in the observation regarding human speakers is that while we tend to have no problem adapting our language to new domains and new dialogue partners, we frequently resist (and even protest) changes to our shared general vocabulary and grammar.

7 Multilinguality and Domain-specific Grammar

Regarding the division of labour at the level of syntax and semantics, general forms for dialogue moves are specified in a domain-independent grammar. This grammar is defined using GF (Grammatical Framework) Resource Grammar Library (Ranta 2004). The general grammar is then fleshed out by the domain-specific grammar (written in XML), which supplies the surface forms associated with domain-specific entities, predicates and actions. The XML format allows taking advantage of GF resource grammars without knowing GF.

A major benefit of GF is that it provides resource grammars for a large number of languages, which simplifies localization of dialogue system applications to new languages. An interesting question arises here with respect to how language-dependent the semantics implemented in the domain and grammar is. It is well-known that languages differ with respect to their semantic categories, but arguably many of these differences are at the level of language in general rather than at the level of specific domains. When building dialogue system applications and porting them to new languages, it is often implicitly assumed that activities and domains are invariant across languages. Insofar as this is true, it may be that differences between languages at the general (domain-independent) level are more or less cancelled out in the process of adapting the language to the domain (either by design or through interaction).

Still, it may be that different languages will be differently equipped to handle certain domains, insofar as semantic distinctions in each domain derive from general distinctions in the language. If this is true, this means that the process of achieving a domain language for a domain may differ between languages, and may be easier for some domain + language pairs than others. At the present time, this is just a speculation, but if (when) future dialogue systems become able to interactively coordinate on new meanings and learn from experience how to talk about new activities, it will become a testable hypothesis.

8 Conclusions

We have illustrated a design philosophy for dialogue system development, where domain-specific domain knowledge is clearly separated from the logic for generic dialogue capabilities. We hope that this provides a useful illustration of how one may approach the division of labour between general and domain-specific syntax, semantics and pragmatics in a dialogue system. We also briefly discussed issues of multilinguality and the possibility of dialogue systems learning (rather than being programmed), and coordinating with users on, domain-specific meanings.

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Same Syntax, Different Semantics: A Compositional Approach to Idiomaticity in Multi-word Expressions

Timm Lichte • Laura Kallmeyer

Abstract Idiomatic multi-word expressions (MWE) are commonly analyzed as phrasal units in syntax, in addition to their literal counterparts, and accordingly introduce syntactic rather than semantic ambiguity. However, an analysis of idiomaticity based on syntactic ambiguity is disadvantageous, because it neglects recent psycholinguistic findings about the processing of idiomatic MWEs, and it furthermore obscures the possible connection between their literal and idiomatic meaning. In this contribution, we sketch an alternative analysis, employing the framework of Lexicalized Tree Adjoining Grammar (LTAG), where idiomaticity is not subject to syntactic ambiguity, but emerges in the semantics.

Keywords multi-word expression · ambiguity · LTAG · Frame Semantics

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1 Introduction

Multi-word expressions (MWE) consist of multiple lexemes that combine in some idiosyncratic, unpredictable or "idiomatic" way (Sag et al. 2002, Baldwin & Kim 2010). This combinatorial idiomaticity can manifest in different aspects of an MWE, for example in its syntax, semantics, pragmatics or statistics. In this work, we are mainly interested in semantic idiomaticity, which basically follows from the availability of a literal and an idiomatic meaning. Take, for example, the complex expression *to spill the beans*. Its literal meaning is 'to spill the beans' (obviously), whereas its idiomatic meaning is rather something like 'to divulge/reveal some secret(s)'.

Semantically idiomatic MWEs such as *to spill the beans* are said to be DECOMPOSABLE, whenever a quasi-bijective correspondence between components of the literal and the idiomatic meaning can be established. The crucial pairs in the above example are 'spill'–'divulge/reveal' and 'beans'–'secret(s)'. However, this doesn't hold for all the semantically idiomatic MWEs, a typical example being *to kick the bucket* with its idiomatic meaning 'to die'. Those latter cases therefore get classified as NON-DECOMPOSABLE.

The ambiguity between literal and idiomatic readings can be modeled as the result of either syntax or semantics. In case of SYNTACTIC AMBIGUITY, the literal and idiomatic readings emerge from different syntactic derivations of the same sentence (see section 2). For example, there would be a literal *spill* and an idiomatic *spill* in the lexicon, or even more complex phrasal entries in the idiomatic case, that would independently and alternatively enter into the syntactic derivation.[1] On the other hand, SEMANTIC AMBIGUITY emerges when processing the lexical semantics of only one lexical entry for *spill*, therefore lacking phrasal entries altogether (see section 3). While earlier work, for the most part, has modeled MWEs in terms of syntactic ambiguity, we will elaborate the semantic ambiguity approach in this paper.

Semantic ambiguity approaches have a number of substantial advantages over syntactic ambiguity approaches: firstly, they seem to be more plausible in psycholinguistic terms, as there is evidence that the computation of literal and idiomatic meanings is based on the same syntax (Peterson & Burgess 1993, Wittenberg & Piñango 2011, Wittenberg et al. 2014); secondly, they simplify the parsing process, as only one syntactic derivation has to be performed and the disambiguation step can be delayed; finally, the connection between literal and idiomatic meanings can be made more explicit compared to syntactic ambiguity approaches where literal and idiomatic meanings are assigned to separate lexical entries. On the other hand, we will show that purported disadvantages of semantic ambiguity approaches dissolve under certain implementational assumptions, so that the advantages, particularly of lexical-semantic approaches, prevail.

We will base our implementation on the framework of Lexicalized Tree

[1] Note that by "syntactic derivation" we mean the derivational process, not just the derived syntactic structures.

Adjoining Grammar (LTAG). We conjecture, however, that the covered approaches can in principle be implemented in most other grammatical frameworks as well.

2 Idiomaticity as Syntactic Ambiguity

Syntactic ambiguity is triggered by semantically idiomatic MWEs whenever there are different syntactic derivations for literal and idiomatic meanings. This general approach is found in work across rather heterogeneous frameworks. While calling them "canonical form theories," Pulman (1993) mentions analyses from Transformational Grammar (Chomsky 1980), Lexical Functional Grammar (Bresnan 1982), and LTAG (Abeillé & Schabes 1989, Abeillé 1990, 1995). We might also add recent work in Head-driven Phrase Structure Grammar (Sailer 2003, Soehn 2006, Richter & Sailer 2009) and Sign-based Construction Grammar (Kay et al. in progress).[2] In the following, we will be focusing on LTAG.

2.1 LTAG

An LTAG (Joshi & Schabes 1997, Abeillé & Rambow 2000) consists of a set of ELEMENTARY TREES, which are lexicalized in the sense that at least one leaf node bears a lexical element, that is, a word token. These elementary trees can be combined to yield larger DERIVED TREES using either SUBSTITUTION or ADJUNCTION. Substitution is the replacement of a leaf node of a target tree with an elementary tree, whereas adjunction replaces a non-leaf, that is, an inner node with an elementary tree. Commonly, substitution is used in cases of complementation (including the subject), and adjunction in cases of modification.[3] An example is provided in figure 1.

LTAG is known for providing elegant accounts for a range of multiword expressions with non-compositional meaning (e.g. Abeillé & Schabes 1996). The reason is that elementary trees of an LTAG can be made as large as is necessary to span any multi-word expression, even discontinuous or clausal ones, as elementary trees come with an extended domain of locality (EDL). This can also be observed in the example in figure 1. The EDL property is particularly useful when it comes to inflexible (*by*

[2] It seems that the approach of Fischer & Keil (1996) also runs into syntactic ambiguity.

[3] The exception to the rule are sentential complements, which usually combine with their governor via adjunction, in order to allow for long-distance extraction.

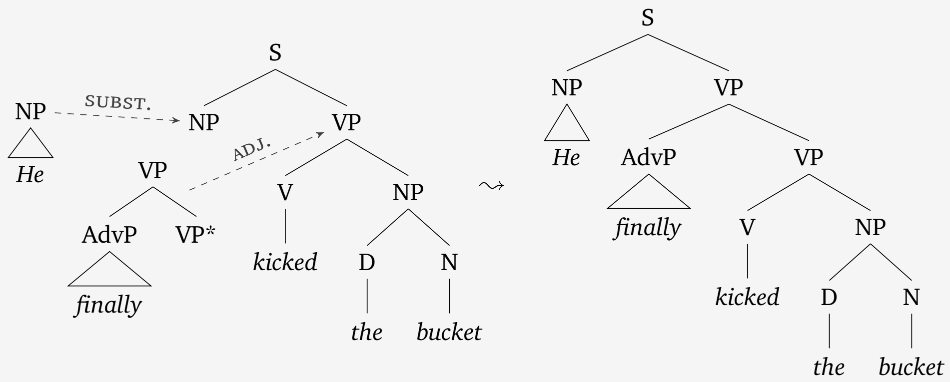


Figure 1 An LTAG derivation of *He finally kicked the bucket*

and large) or syntactically ill-formed MWEs (*kingdom come*), or MWEs with bounded words (*leave sb. in the lurch*). But also the greater flexibility of semantically idiomatic MWEs can be accounted for to some degree. An example is shown in the upper part of figure 2 with a frame-based semantics following Kallmeyer & Osswald (2013). Due to the flexible linking of syntax and semantics by means of interface variables (see the boxed numbers), internal and external modification can be adequately handled. In the idiomatic case, for example, the adnominal adjective *social* in *She kicked the social bucket* (meaning 'Socially speaking, she died') would adjoin to the N-node of *bucket*, but it would correctly modify the *dying* event thanks to the linking via $\boxed{0}$.[4]

By contrast, the literal reading of *kicked the bucket*, as can be seen from the lower part of figure 2, emerges from additional elementary trees in which *kicked* and *bucket* lexicalize separate elementary trees with some literal meaning representation. Hence, based on this sort of proliferation, there are two syntactic ways in which *kicked the bucket* can be derived.

2.2 Problems of Syntactic Ambiguity Approaches

While this sort of model clearly has its virtues, it nevertheless suffers from the disadvantages of syntactic ambiguity approaches already mentioned in section 1, which will be elaborated in the following.

One crucial peculiarity of the model just presented is that it enumerates

[4]See a similar approach using Synchronous TAG in Sailer 2003:(438).

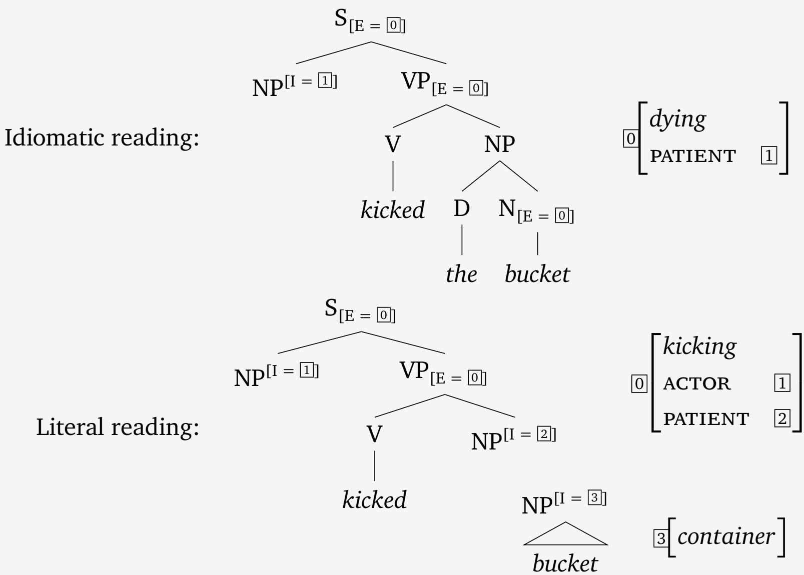


Figure 2 Syntactic ambiguity of *kicked the bucket* induced by disjunction over pairs of LTAG elementary trees and frame semantic representations

idiomatic and literal expressions by assigning a separate elementary tree (or a family of trees) to each of them. Hence, both meanings are based on purely homonymous words, or to put it differently, it falls out as a mere coincidence that words such as the literal *kick* and the idiomatic *kick* happen to be pronounced similarly. This has two immediate consequences: (i) the possible connection between literal and idiomatic meanings of an MWE, for example in terms of register or etymology, is obscured; (ii) regarding the flexibility of idiomatic MWEs, generalizations about variability are at risk of being missed, as Pulman (1993:256–257) notes. He gives examples of lexical variability such as in *put/lay/spread the cards on the table*, and of constructional variability as in *let the cat out of the bag* versus *the cat is out of the bag*. Looking at elementary trees alone, it is obvious that both drawbacks cannot easily be argued away. However, elementary trees of an LTAG are usually described in a metagrammar (using, e.g., XMG; Crabbé et al. 2013), which helps to express generalizations across elementary trees. Hence, within such a metagrammar, it seems rather straightforward to capture at least the lexical and constructional variability that

Pulman brings up.

A more severe drawback touches upon the predictions made regarding the processing costs of MWEs: a syntactic ambiguity approach predicts that MWEs are syntactically more demanding during processing, since potentially two derivations have to be computed, one for the literal and one for the idiomatic meaning. However, psycholinguistic findings seem to suggest that processing costs emerge in the semantics rather than in syntax (Peterson & Burgess 1993, Wittenberg & Piñango 2011, Wittenberg et al. 2014). This contradicting evidence is fostered by general considerations about computational economy: given a parser that implements a syntactic ambiguity approach, it would act inefficiently when parsing MWEs, since it would create the very same syntactic structure several times. Therefore, speaking of parsing efficiency, one would clearly like to place ambiguity at the level of semantics in order to delay disambiguation.

Next, there are a couple of more linguistic problems when accounting for partial uses of decomposable MWEs, that is, instances of pronominalization or isolation of NP-components of an MWE, let alone the "extendability" (Egan 2008) of literal MWE senses. An example of pronominalization due to Riehemann (2001:(229)) is given in (1):

(1) Eventually she spilled all the beans. But it took her a few days to spill them all.

The critical part is *spill them* in the second sentence, where the canonical NP-component of the MWE *spill beans* is replaced by a pronoun.[5] Within an LTAG approach, one could pursue one of at least two modeling strategies: (i) treat the pronoun as a lexicalized leaf node similarly to the NP-component in *spill beans*, or (ii) treat the NP-component as an unlexicalized leaf node into which only *beans* and *them* can be substituted, hence assigning it the status of a highly restricted argument slot. The first strategy would be liable to lose contact with a general theory of pronominalization,[6] while the second strategy would make some ad hoc categories

[5] Riehemann (2001:207) tentatively assumes that pronominalization in *spill them* is licensed by a more general, metaphorical use of *spill*, which allows for combinations with a wider range of NPs, such as in *spill the secrets*.

[6] Thanks to Manfred Sailer for pointing this out.

necessary in order to rule out lexical anchors other than *beans*.

A case comparable to pronominalization, also having to do with the flexible use of MWEs, is the isolation of the NP-component. The following example is due to Manfred Sailer and Sascha Bargmann (pers. comm.):

(2) Pat pulled some strings for Chris. But Alex didn't have access to any strings.

In the second sentence, the NP-component *any strings* occurs isolated from the rest of the MWE, namely, the verb *pull*, while still bearing the idiomatic meaning 'connections'. This sort of isolation can only be modeled by a special elementary tree of *strings*, which is, however, difficult to limit to certain discourse contexts as in (2).

Maybe an even more extreme case of flexibility is observed by Egan (2008:(13b)):

(3) If you let this cat out of the bag, a lot of people are going to get scratched.

The remarkable property of the conditional in (3) is that *to get scratched* resumes the figurative mapping of *let this cat out of the bag*, even though *let this cat out of the bag* is part of the antecedent clause. Egan (2008) therefore calls *to get scratched* an EXTENSION of the MWE and he rightly suspects that syntactic ambiguity approaches face difficulties in covering these extensions. The only viable strategy, so it seems, is to extend the grammar by (probably masses of) secondary MWEs such as *to get scratched*, which would still be hard to limit to contexts which contain the primary MWE.

The last group of intricate uses of idiomatic MWEs that we will address here is related to modification. In the previous section, we have already seen that simple cases of internal and external modification can be dealt with using the appropriate linking pattern between syntactic nodes and positions in the frame semantic representation. This only works for modifiers pertaining to the idiomatic sense of the MWE. However, as Ernst (1981:(27)) has shown, the modifier can add to the literal meaning as well:

(4) The federal agency decided to take the project under its well-muscled

wing.

Here *well-muscled* is supposed to mean something like 'powerful'. Ernst also provides an example of idiomatic adnominal modification with *federally-funded*. In fact, it is not difficult to come up with an example in which these sorts of modification, which pertain to either idiomatic or literal meaning dimensions, are mixed:

(5) The federal agency decided to take the project under its well-muscled, federally-funded wing.

A similar case of instant multi-dimensionality is found in Ernst's category of "conjunction modification," which he exemplifies with the following datum (Ernst 1981:(10)):

(6) Malvolio deserves almost everything he gets, but … there is that little stab of shame we feel at the end for having had such fun pulling his cross-gartered leg for so long.

The adjective *cross-gartered* modifies the literal meaning of *leg*, which "refers to Malvolio's real, flesh-and-blood leg," but it is not figuratively mapped onto the co-existing idiomatic meaning of *pull sb.'s leg*. Ernst resolves this as an extra proposition that is added through conjunction – therefore the name. It is not at all obvious how literal, mixed, and conjunction modification could be satisfactorily treated within a syntactic ambiguity approach. Since the connection between literal and idiomatic meaning is generally obscured, the modifiers, like the MWEs, would have to be multiplied for each of the meaning dimensions.

To avoid false expectations: we won't solve all these flexibility issues here. This would eventually mean to close the gap to a profound theory of metaphor. Still, semantic ambiguity approaches, particularly the inference-based approaches, seem to be a better starting point.

3 Idiomaticity as Semantic Ambiguity

Put simply, semantic ambiguity emerges whenever the literal and the idiomatic reading of an MWE cannot be traced back to syntactic ambiguity. Hence there is only one syntactic derivation for both readings, and the semantic ambiguity must be either induced by lexical specification or by global quasi-inference rules. Compared to syntactic ambiguity approaches, semantic ambiguity approaches are applied rather seldom, let alone in a formally explicit fashion. In the next two sections we will first review earlier work, and then present our own implementation based on LTAG and frames in section 4.

3.1 Previous Lexical-semantic Approaches

The only formally more or less explicit lexical-semantic approach that we are aware of has been presented by Gazdar et al. (1985:sect. 10.7). In their proposal, the components of decomposable MWEs are assigned two meaning constants (of Intensional Logic), as can be seen from (7a), namely, one for their literal and one for their idiomatic meaning. We separate them with the ambiguity symbol || from Wurm & Lichte (2016):

(7) a. *spill* := spill′ || spill-idiom′
beans := beans′ || beans-idiom′
b. spill-idiom′ (beans-idiom′): defined
spill-idiom′ (beans′): undefined
spill′ (beans-idiom′): undefined

These meaning constants are interpreted as partial functions (contrary to what was usual in Intensional Logic at that time).[7] The reason to choose partial functions is that this makes it possible to restrict the emergence of idiomatic meanings to the complete occurrence of the MWE. Thus, literal and idiomatic meaning components cannot be properly combined, since the result would be undefined such as in (7b).

Note that Gazdar et al. (1985:244) propose to treat non-decomposable MWEs as "syntactically complex lexical items," hence within a syntactic ambiguity approach. However, we think that in principle partial functions can also be used when dealing with non-decomposable MWEs:

(8) a. *kick* := kick′ || kick-idiom′
bucket := bucket′ || bucket-idiom′
b. kick-idiom′ (bucket-idiom′): defined
kick-idiom′ (bucket′): undefined

[7] Pulman (1993) therefore calls it a "partial-function approach."

kick′ (bucket-idiom′): undefined

As with decomposable MWEs, the interpretation is only defined if the right meaning constants are combined via functional application. Of course it needs to be clarified what bucket-idiom′ denotes. In section 4 we will basically state that it has the same denotation as kick-idiom′, namely, ‘die’, and both denotations get identified upon composing kick-idiom′ and bucket-idiom′.

The lexical-semantic approach of Gazdar et al. has several general advantages over the syntactic ambiguity approach based on LTAG: it yields a unified syntax for idiomatic and literal readings, and, following this, appears to be psycholinguistically more realistic. However, it also comes with considerable, general drawbacks. One is the invention of masses of meaning constants that essentially reflect morphological properties. There is no genuinely semantic motivation for having something like a spill-idiom′ predicate, when it conceptually coincides with divulge′. These predicates are needed only in order to capture constraints on the surface structure, that is, at word level.

Another drawback is computational, as Pulman (1993) points out, namely, the introduction of extra ambiguity and following this a “considerable combinatorial explosion.” This might come as a surprise given that yielding a unified syntax was thought to delimit computational effort. The reason is that ambiguity resolution now takes place at word level, not at the phrasal level. Therefore, the grammar has to try out many illicit combinations of idiomatic and literal word meanings, without taking phrasal information into account.

Pulman, furthermore, claims that Gazdar et al.’s approach either under- or overgenerates, for example, when treating the following relative clause (Pulman 1993:(50)):

(9) He tried to brake the ice which inhibited our conversation.

The issue arises when the relative pronoun *which* receives the idiomatic interpretation of *ice*. If this is the case, then the interpretation of the verb of the relative clause, *inhibited*, must be made compatible, that is, ambiguous. However, this then also licenses the idiomatic interpretation of sentences like the following (Pulman 1993:(51)):

(10) The ice inhibited our conversation.

Pulman questions the immediate availability of the idiomatic interpretation of (10) in contrast to (9).

Similarly, the partial-function approach is at risk of overgeneration when dealing with cases of partial use and, in particular, extendability such as in (3) – at least it will add substantially more ambiguity. Regarding literal, mixed and conjunctive modification, the situation is even worse: it is not conceivable how this approach, in which idiomatic and literal meaning dimensions remain de facto disconnected, could satisfactorily handle those cases. What Gazdars et al.'s partial-function approach can rather nicely deal with, however, are cases of lexical variability, since variants can be assigned the same idiomatic meaning constant (Gazdar et al. 1985:239–240).

Lastly, note that the relation between distinct meaning potentials is notoriously unclear in lexical semantics. In (7) and (8), we used the symbol $\|$ to discriminate between literal and idiomatic meaning, borrowing it from Wurm & Lichte (2016). But what does $\|$ mean or correspond to? The obvious choice, namely, disjunction, is far from adequate (see Poesio 1996, Wurm & Lichte 2016): The propositional meaning of *If he kicked the bucket, the water would spill over the floor* is not something like ('he died' $\vee$ 'he kicked the bucket') $\rightarrow$ 'the water would spill over the floor', or the equivalent ('he died' $\rightarrow$ 'the water would spill over the floor') $\wedge$ ('he kicked the bucket' $\rightarrow$ 'the water would spill over the floor'). What is the relation then? And how does it work out compositionally? As far as we can see, Gazdar et al. remain silent about these fundamental questions. See Wurm & Lichte 2016 for some general algebraic considerations.

3.2 Previous Inference-based Approaches

In the light of the problems encountered in the lexical-semantic approach of Gazdar et al. (1985), Pulman (1993) proposes to deduce the idiomatic meaning from the literal one by means of "quasi-inference."[8] In this approach, MWE-components are equipped with their literal meaning only, whereas the idiomatic meaning comes in later once the complete MWE has been seen. An example of the style of such quasi-inference rules is

[8]Another, yet very informal, inference-based approach is found in Egan (2008).

shown for the MWEs *kick the bucket* and *spill the beans* in (11a):

(11) a. $\forall x, y.\text{kick}'(x, y) \wedge \text{bucket}'(y) \approx \text{die}'(x)$

b. $\forall x, y.\text{spill}'(x, y) \wedge \text{bean}'(y) \approx$
$\exists z.\text{divulge}'(x, z) \wedge \text{information}'(z)$

While it is obvious that (11a) and (11b) are not meant to be regular inference rules (since the left-hand side can be false with the right-hand side being true, and vice versa), Pulman remains vague about the exact meaning of ≈. It is supposed to mean that if the left-hand side is "matched" in the logical form, the right hand side meaning is "possible" as well, "perhaps" replacing the literal meaning "depending on the context" (p. 262). Furthermore, as Pulman's inference rules are purely semantic, he needs to limit their scope by "lexical indexing," that is, by attaching a set of lexical items to each of the rules. For (11a), this would be the set {*kick*, *the*, *bucket*}, which would have to be a subset of a given sentence in order for the rule to apply.

Similarly to Gazdar et al.'s partial-function approach, Pulman's quasi-inference rules treat the distinction between literalness and idiomaticity mainly in the semantics, which leaves the syntax unified and thereby consistent with psycholinguistic findings. In contrast to partial functions, however, quasi-inference rules seem to reduce the degree of local ambiguity, because the idiomatic meaning does not emerge per word. Instead, it is based on larger, that is, phrasal chunks of literal meaning. Moreover, the domino effect of artificial idiomatization, which Pulman showed with the relative clause in (9), can be avoided (let alone partial functions in general).

The main problem of Pulman's implementation is its vagueness, which makes it virtually impossible to see how extendability, challenging cases of modification, etc. can be treated without running into vast overgeneration or yielding an incorrect truth-conditional semantics. Even in basic cases, the use of lexical indexing for restricting quasi-inference seems to be too permissive.[9] It is also not settled that the inference-based approach

[9]There is one aspect of overgeneration, however, that is deliberately prompted: quasi-inference rules do not check for the syntactic construction from which the literal meaning emerges. Therefore, they can be applied even to passive constructions like *the bucket*

is indeed computationally lighter than the lexical-semantic approach, for quasi-inference rules seem to be potentially non-monotonic and might apply at any time and in any order. Finally, it should be borne in mind that the sharp procedural distinction between literal and idiomatic meaning is not uncontroversial in the psycholinguistic and philosophical literature (see, e.g., Récanati 1995, Gibbs 2002, Wearing 2012).

4 A New Lexical-semantic Approach

The main problem of the lexical-semantic approach of Gazdar et al. (1985) is that it fuses morphological constraints with semantic representations. What we therefore propose is to disentangle these two aspects and treat semantics and morphology as separate but interrelated dimensions. To this end, we enrich the frame semantic representations from figure 2 with SEM and MORPH features, while the syntax remains a regular LTAG. Because special elementary trees for MWEs, such as the first one in figure 2, are missing, the morphological features are necessary for confining the context where the idiomatic meaning emerges.

4.1 Elementary Structures

Our proposal is fleshed out in figure 3 based on the lexical entries for *kicked* and *bucket*. In either case, the first ||-disjunct corresponds to the literal meaning and the second one to the idiomatic meaning. Similarly to the syntactic ambiguity approach in figure 2, the elementary trees and the SEM-MORPH representations are linked via interface variables (see the boxed numbers). As for *kicked*, the subject NP (with variable $\boxed{1}$) is linked to the actor of a *kicking* frame in the literal case, and to the patient of a *dying* frame in the idiomatic case.[10] The object NP (with variable $\boxed{2}$), however, is linked to some component of the verbal frame only in the literal case, whereas, in the idiomatic case, it is linked to the verbal frame as

is kicked or *the breeze was shot* and yield their idiomatic meaning, contrary to what is consensus in the literature (Sag et al. 2002, Baldwin & Kim 2010). Pulman argues that those constructions are incompatible with idiomatic interpretations on pragmatic, that is, information-structural grounds. We will largely ignore aspects of constructional fixedness in this work.

[10] Boxed numbers with a prime are a proxy for a link to the SEM part, more precisely, they invoke a path equation of the following kind: $\boxed{n}' = \boxed{n}$SEM. This means that $\boxed{n}'$ is the value of SEM of $\boxed{n}$.

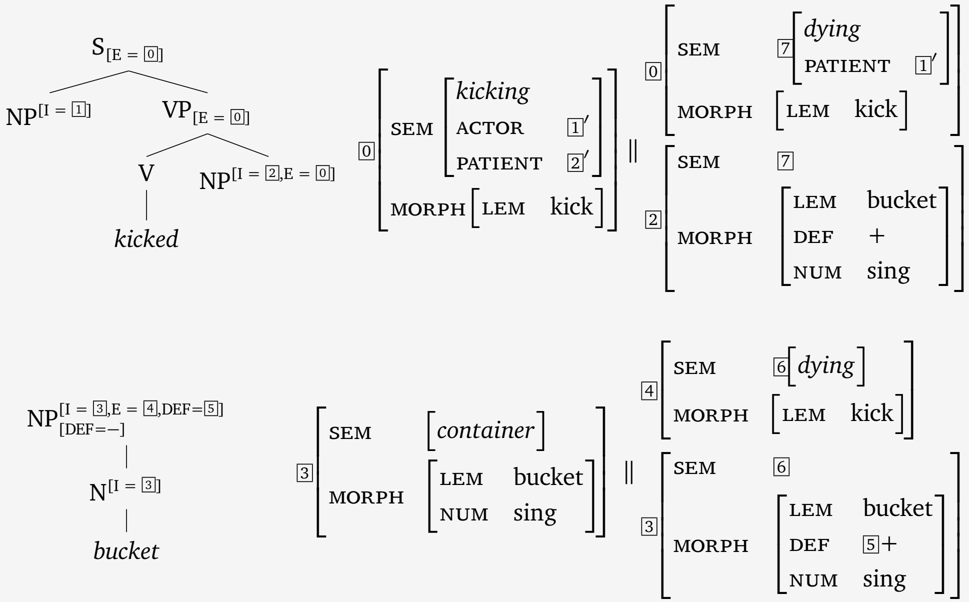


Figure 3 Entries for *kicked* and *bucket* within a semantic ambiguity approach based on LTAG

a whole, while the MORPH feature anticipates the substitution of *bucket*. More precisely, the object NP points to a SEM-MORPH structure in which the SEM value is identical with the SEM value of the SEM-MORPH structure of the verbal projection (with variable $\boxed{0}$).[11] Yet as different as they may be, the literal and idiomatic ||-disjuncts are explicitly connected by sharing interface variables, namely, $\boxed{0}$ and $\boxed{1}'$, which link them to the same elementary tree.

One noticeable property of this proposal, which we call IDIOM MIRRORING, is that the idiomatic meaning is spread over all the components of the MWE. Therefore, also the NP-component carries the meaning of the whole, that is, *bucket* carries the *dying* frame in figure 3. While this might look odd at first, it is necessary in order to allow modification at *bucket* (via adjunction at the N-node, see section 4.3) to yield wide scope. Idiom mirroring is justified on independent grounds as well, since *bucket*,

[11]Note that the value of MORPH is a simple feature list rather than a recursive typed feature structure, which is the value of SEM following Kallmeyer & Osswald (2013).

in some cases, can contribute the idiomatic meaning even when isolated from *kicked*, for example, in *bucket list*.[12]

Note that the determiner *the* does not take part in idiom mirroring in figure 3. This seems justified, as *the* is a semantically bleached function word. Instead the adjunction of standard *the*, which aims at the NP-node of *bucket*, is enforced by the otherwise pending feature clash of the DEF features.[13] It should be stressed that the features in figure 3 (and the figures to come) are chosen for expository reasons. It would be equally viable to use DEF only on the morpho-semantic side, and express the fact that the count noun *bucket* generally requires a determiner by means of another more generic feature (e.g., DET). Conversely, to rule out definite determiners that do not yield the idiomatic reading as in *He kicked his bucket*, the DEF feature could be further refined. A far more intricate question is what happens to the semantic contribution of *the*, bleached as it may be, in the idiomatic case.[14] Assuming that *the* contributes some sort of definiteness operator that selects a specific antecedent from context, the linking in figure 3 would predict that, upon adjoining *the* into the NP-node of *bucket*, the definiteness operator will take wide scope over the dying event. Thus, *kicking the bucket* would denote a specific dying event. This, however, seems questionable given embeddings such as *Kicking the bucket was easy* that clearly lack such a denotation. Yet, working out the subtle details of this part of the story must be left to future work.

It is instructive to compare this with the analysis of a decomposable MWE such as *spill beans*. The relevant entries are shown in figure 4. Comparing them to the entries in figure 3, the high degree of structural similarity is striking. Firstly, the syntactic trees are basically the same, except for the lexical anchor of course, and they conform to the commonly assumed elementary trees in LTAG. Secondly, once again we make use of idiom mirroring in the idiomatic meaning components, even though the

[12] Thanks to Manfred Sailer for pointing out this fact.

[13] In LTAG with feature structures, every node consists of top and bottom feature structures that get eventually unified, that is, after substitution and adjunction have taken place. Therefore, if no determiner was adjoined at the NP-node of *bucket*, the equation $\boxed{5} = -$ would hold after top-bottom unification, which contradicts the specification $\boxed{5} = +$ on the idiomatic side.

[14] Thanks to Jamie Findlay for making us aware of this issue.

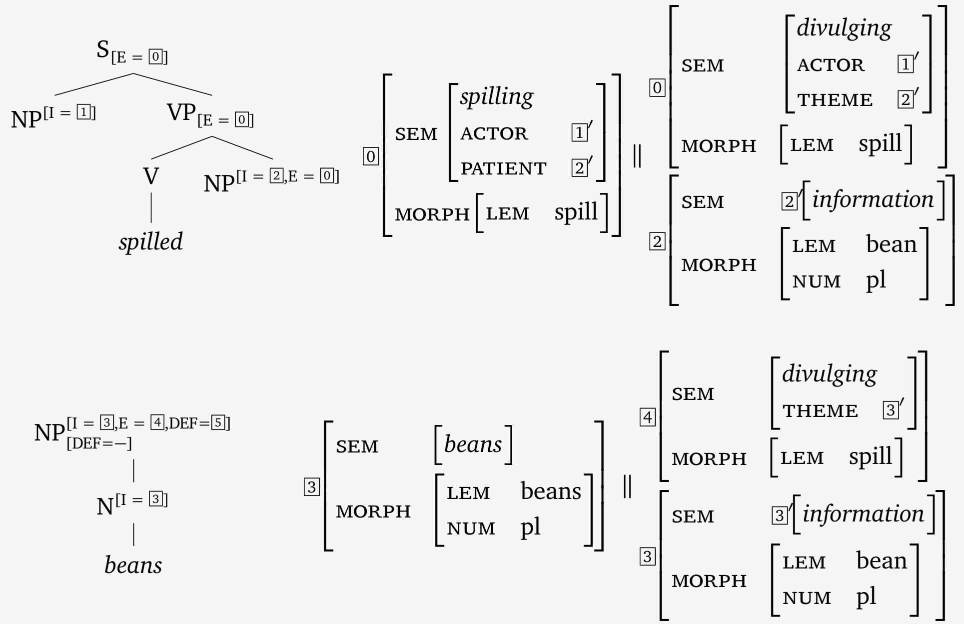


Figure 4 Entries for *spilled* and *beans* within a semantic ambiguity approach based on LTAG

SEM values of $\boxed{3}$ and $\boxed{4}$ now differ in order to allow for internal modification (see section 4.3). This sort of uniformity is particularly rewarding from the point of view of the metagrammar (see section 2.2), because it supports a lean description of the generalizations across those and other entries.

4.2 Composition with ||-Disjunctions

Following Kallmeyer & Osswald (2013), upon substituting or adjoining elementary trees, the feature structures of affected nodes are unified, and consequently their interface variables. Thus when *bucket* gets substituted into the object NP leaf of *kicked*, the identities $\boxed{2} = \boxed{3}$ and $\boxed{0} = \boxed{4}$ are obtained. Furthermore, the ||-disjunctions are unified in a straightforward distributional way by which every ||-disjunct gets unified with each of the

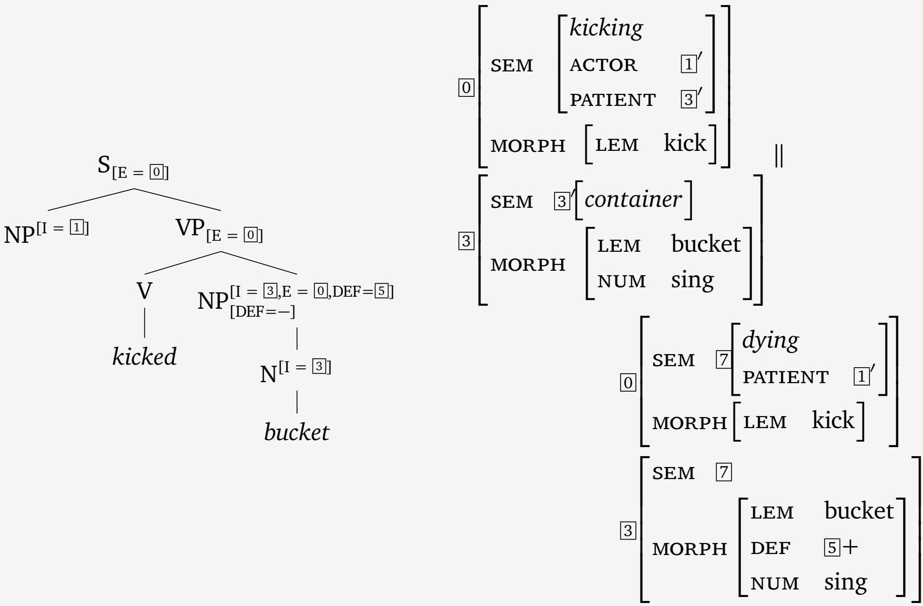


Figure 5 Result of substituting the elementary tree of *bucket* into the elementary tree of *kicked* (the determiner *the* still needs to be adjoined)

||-disjuncts of the other tree (but only two times successfully).[15] The result of all this is shown in figure 5. Note that the SEM-MORPH side remains multi-rooted, which is intended, and connected to the syntactic tree.

There are two other important ramifications of this compositional approach: (i) the frame of the verbal head must be visible in the NP-slot (via the E feature), otherwise the idiomatic meaning of *bucket* would be generally available; (ii) the approach seems to suggest that idiomatic *kick the bucket* is syntactically as flexible as the literal counterpart, which many would consider too permissive. In fact, we adopt the view of Pulman (1993) that syntactic inflexibility results from a mismatch between information structure and semantics.[16] But if this view was not shared, one could flexibly adjust the ||-disjuncts of, for example, passive elementary

[15] In formal terms, the following distributional equation holds: $(a \parallel b) \sqcup (c \parallel d) = (a \sqcup c) \parallel (a \sqcup d) \parallel (b \sqcup c) \parallel (b \sqcup d)$

[16] In fact, Manfred Sailer has informed us that there is (rare) evidence for passivization of idiomatic *kick the bucket*, namely, *The bucket will be kicked*.

trees to only ship literal meanings.

Finally, the readings of a lexeme are immediately available when instantiating its elementary tree. This could be taken to contravene psycholinguistic results that suggest that readings are not equally accessible. Putting distinct weights on the disjuncts, however, might solve this issue, and ease the potential of combinatorial explosion.

Hence, when comparing this implementation of a semantic ambiguity approach with the one of Gazdar et al. (1985) sketched in section 3.1, two substantial improvements become evident: firstly, there are no ad hoc meaning constants, and morphosyntactic restrictions are expressed where they belong; secondly, local ambiguity is considerably diminished, since phrasal cues can be used straightforwardly. But also the empirical coverage can be improved on, as the following section will show, where we will treat cases that were considered challenging in the preceding sections.

4.3 Analysis of Modification and Partial Use

Recall the sorts of adjectival noun modification inside idiomatic multiword expressions we mentioned in section 2:

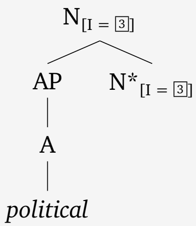
(12) a. He kicked the political bucket. (external mod.)
'Politically speaking, he died./His political life ended.'

b. He spilled the political beans. (internal mod.)
'He revealed political secrets.'

c. We took it under our well-muscled, federally-funded wing. (mixed mod.)
'We strongly protected it with the aid of federal funds.'

d. We pulled his cross-gartered leg. (conjunctive mod.)
'We teased him and he had a cross-gartered leg.'

External and internal modification in (12a) and (12b) are treated similarly to the syntactic ambiguity approach, namely, by adjunction at the N-node of *bucket* and *beans* respectively. The different scopes of the modifiers result from the different linking by means of interface variables: in the case of external modification, the N-node is linked with the idiomatic meaning of the whole MWE (in figure 3 with 'die' via $\boxed{3}$), whereas in the case of internal modification, there is a link with the proper idiomatic meaning of the noun (in figure 4 with 'information' via $\boxed{3}$). A tentative entry for the



$$\boxed{3}\left[\textsc{sem}\ \boxed{3}'\left[\textsc{domain}\quad \textit{politics}\right]\right] \| \boxed{3}\left[\textsc{sem}\ \boxed{3}'\left[\textsc{about}\quad \textit{politics}\right]\right]$$

Figure 6 Entry for the adjectival nominal modifier *political*

adjective *political*, which can be used for both sorts of modification and is therefore ambiguous, is shown in figure 6.[17] The first ||-disjunct is supposed to cover the external modification case and is therefore necessarily vague, as it is hard to pin down exactly what the meaning of those "domain delimiters" (Ernst 1981) is.[18] The resulting derived tree after adjoining the entry for *political* into the derived tree of *kick bucket* from figure 5 is shown in figure 7. Note that the semantic composition arises from the final top-bottom unification at the N-node that dominates *political bucket*. In figure 7, this unification has already been performed. In this example, we assume that the ABOUT feature in the second ||-disjunct of *political* is incompatible with both types, *container* and *dying*. Therefore, only the DOMAIN reading shows up.

What makes (12a) also challenging, is that there seem to be two figurative interpretations in a row: at first, *kick the bucket* is interpreted as 'die' or 'ending of a (biological) life', and upon adding *political*, the meaning 'ending of a political career' emerges, drawing upon the general conceptual metaphor that 'career' can be seen as 'life'. Moreover, note that some features seem to be prohibited, for example MANNER: one cannot use *painful* as a modifier of *bucket* with the idiomatic meaning that the manner of dying was painful:

(13) #He kicked the painful bucket.
'He died painfully.'

[17]The presented adjectival entries are tentative in the sense that they are not at all meant to be exhaustive, but to only cover some distinctions that are immediately relevant to make our examples work.

[18]Metalinguistic modifiers such as *proverbial* are similar in this respect.

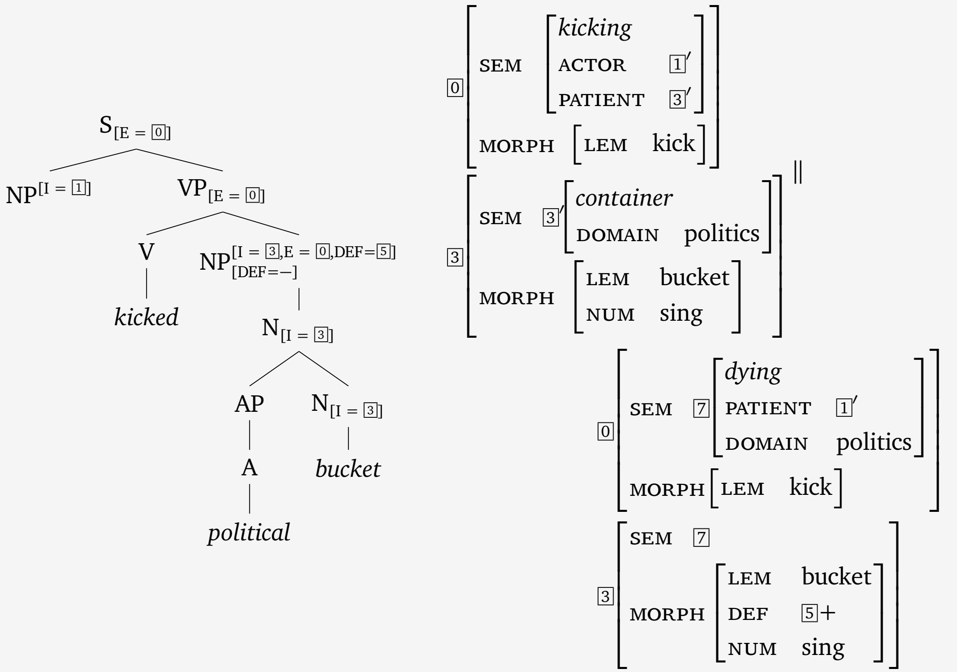


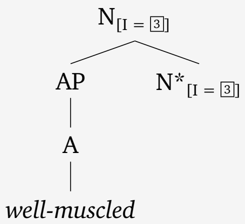
Figure 7 Result of adding the lexical entry in figure 6 to the derived structure in figure 5; the tree of *political* has been adjoined to the N-node of *bucket*

Surprisingly enough, the option with adverbial modification is acceptable on an idiomatic reading:[19]

(14) He painfully kicked the bucket.
‘He died painfully.’

Given these observations, it seems possible to modify the manner denotation of the MWE from the “outside” – but why not from the “inside”? One explanation could be that something is wrong with our analysis, for example, the linking of the I feature and the overall event (see label $\boxed{3}$ in figure 7), or the assumption that *bucket* mirrors the idiomatic meaning of the whole MWE. Fortunately, there is another and, in our opinion, far more interesting explanation, namely, that the idiomatic interpretation

[19]We owe Christopher Piñón this observation.



$$\boxed{3}\left[\textsc{sem}\ \boxed{3}'\begin{bmatrix} \textit{body-part} & \\ \textsc{muscles} & \left[\textsc{extent}\quad \textit{good}\right] \end{bmatrix}\right] \parallel \boxed{3}\left[\textsc{sem}\ \boxed{3}'\left[\textsc{potency-level}\quad \textit{high}\right]\right]$$

Figure 8 Entry for the adjectival nominal modifier *well-muscled*

of *kick the painful bucket* is unavailable because of the awkward *literal* interpretation of *painful bucket*. This might look like an ad hoc escape hatch, but, in fact, the persistence of literal fragments under an overall idiomatic interpretation can also be observed with conjunctive modification (see below). Therefore, we think that this line of thought should be taken seriously, even though the ramifications within our framework are hard to assess at this point. Given these complications, we leave it to future work to examine whether the general ambiguity approach sketched in figure 6 is actually sustainable.

The challenge of mixed modifications such as in (12c) is that one of the modifiers (*federally-funded*) pertains to the idiomatic meaning of the MWE, while the other one (*well-muscled*) modifies the literal part. Thus, there are rather two questions: (i) how does *well-muscled* access the literal meaning of the MWE, and (ii) how is this transferred to the idiomatic meaning, to which *federally-funded* applies? Note that the linear order of *well-muscled* and *federally-funded* is not fixed. The simplest and somewhat obvious solution is to make use of ambiguous entries again.[20] This strategy is followed in the entry in figure 8, where the first ||-disjunct corresponds to the literal meaning, and the second one to the idiomatic meaning.[21] Now, the question is: how can this possibly *not* overgenerate? What prevents the combination of the literal part of *well-muscled* with the idiomatic

[20]Another more ad hoc solution would be to encode the idiomatic part of the modifier already in the entry of the MWE. However, since the class of adjectives that can modify idiomatic *wing* is presumably not closed, and since *well-muscled* is amenable to this interpretation also with other nouns, this solution is not preferred.

[21]Note that the idiomatic meaning of *well-muscled* is not stipulated in accordance with the idiomatic meaning of *wing* but is seen to follow from general conceptual metaphors that can be formalized as quasi-inference rules (see section 5).

part of *wing*? The answer is: the type system. Remember that the frame semantic objects are typed, hence we assume that the literal type (*body-part*) is not unifiable with the idiomatic type of *wing*. Therefore, what will happen is that only type-compatible parts will unify, regardless of whether they correspond to the literal or idiomatic meaning.

However, this ambiguous-entries approach comes to its limits when conjunctive modification as in (12d) is considered. The crucial difference from the cases of the last two paragraphs consists of the peculiar way the modifier gets interpreted: the adjectival modifier *cross-gartered* is interpreted only literally, while the MWE *pull his leg* may nevertheless receive an idiomatic interpretation. In other words, the modifier may drop out of the idiomatic interpretation, still (or for this very reason) giving rise to an inference based on the literal interpretation. A possible interpretation of (12d) therefore is 'we made fun of him and he has a cross-gartered leg'. But how can we yield this interpretation with an approach like in figures 6 and 8 that separates literal and idiomatic meaning into different ||-disjuncts? The prospects seem to be the following, unfortunately: either the idiomatic interpretation does not emerge, because it is incompatible with the literal meaning of *cross-gartered*, or we add to *cross-gartered* some compatible, yet bleached idiomatic meaning. In the latter case, which is problematic in many respects, the "conjunctive" proposition ('he has a cross-gartered leg') could nevertheless get lost, since there would be at least one ||-disjunct with the bleached idiomatic meaning that could be used by itself. The basic problem therefore seems to be that there is no way to keep track of which ||-disjunct represents the idiomatic meaning, and which one the literal meaning. If this distinction was available, the condition could be imposed that the bleached idiomatic meaning may be used only if the literal meaning applies too. In this respect, the inference-based approach, to which we will turn in section 5, seems to be better off, as it sharply distinguishes between those two. However, we think that the inference-based approach eventually runs into the same difficulties as the lexical-semantic approach. What is needed instead is the possibility for the propositional interpretation of *parts* of the literal meaning, for example, the literal interpretation of *cross-gartered leg*, but not of *pull*, in (12d). It is not yet clear to us whether this kind of granularity can be achieved within the presented ambiguity framework.

Another challenging sort of modification that we mentioned in section 3 is modification by a relative clause as in (15), repeated from (9):

(15) He tried to brake the ice which inhibited our conversation.

Pulman (1993) argues that this sort of modification is problematic for Gazdar et al.'s lexical-semantic approach: since *which* is assigned the idiomatic meaning of *ice*, one has to assume a compatible partial function to be the meaning of *inhibited*. This, however, leads to overgeneration as *inhibited* now can combine with idiomatic *ice* alone. Fortunately, this issue does not arise within the presented LTAG approach, simply because of what we have called idiomatic mirroring above: idiomatic *break* not only constrains the object noun to be *ice* (similarly to Gazdar et al.'s partial functions), but *ice* as well constrains the governing verb to be *break*. Hence the constraints are effective in both directions, and this ultimately prevents idiomatic *ice* from going astray. Moreover, thanks to the division between SEM and MORPH, the relative pronoun *which* can be made to only refer to the semantics of idiomatic *ice*, so that *inhibited* may remain agnostic concerning the idiomatic/literal status of the semantics of the relative pronoun.

Finally, in section 2, we discussed three sorts of a partial use of MWE-components, repeated in (16) (excerpts from (1), (2) and (3)):

(16) a. [spill beans] ... to spill them all. (pronominalization)
b. [pull strings] ... didn't have access to any strings. (isolation)
c. [cat out of the bag] ... a lot of people are going to get scratched. (extension)

The common feature of (16a)–(16c) is that there is a close, preceding discourse context in which the full MWE is overtly realized. This specificity of the context is indicated by the material inside squared brackets. Hence, pronominalization of *beans* in (16a) is said to be only possible if there is a full realization of *spill beans* in the preceding context, and similarly in (16b) and (16c). To capture this in an adequate way, an approach would have to allow for the access of discourse information in defining, for example, the anaphoric function of *them* and relaxing the constraints of idiomatic *spill* so that it can combine with *them* given an appropriate context. It is obvious that our approach, as is, cannot account for partial use, for the simple reason that discourse structure is not part of the model. It is also obvious, however, that we will need concurrent access to literal and idiomatic meaning (particularly for the case of extension in (16c)), and that we therefore have to look for the best-fitting model among the semantic-ambiguity approaches, not the syntactic-ambiguity approaches.

In sum, the presented lexical-semantic approach based on LTAG and SEM-MORPH descriptions supports a unified, compositional syntax, avoiding some technical and empirical shortcomings of the partial-function approach of Gazdar et al. (1985). We also showed that our approach can handle a range of challenging cases of modification, including cases of modification by relative clauses that are considered problematic for Gazdar et al.'s approach. Yet it remains to be seen whether and how cases of partial use can be integrated, once discourse structure is available.

5 A Similar Inference-based Approach?

In section 3.2, we discussed Pulman's proposal of quasi-inference rules, that is, global entailments, as an alternative to our and Gazdar et al.'s lexical-semantic approach. Those entailments are global in the sense that they in principle apply independently from both the lexicon and the syntactic derivation. We concluded that the formalization of quasi-inference rules, at least as far as Pulman's implementation is concerned, leaves much to be desired. In this section, we try to explicate the notion of quasi-inference rules by targeting some of the central intuitions that Pulman expresses.

Recall that Pulman would probably write down the following quasi-inference rule to deduce the idiomatic meaning of *kick the bucket* from the literal one (repeated from (11a)):

(17) $\forall x, y.\mathrm{kick}'(x, y) \wedge \mathrm{bucket}'(y) \approx \mathrm{die}'(x)$

The big question here is what $\approx$ is supposed to mean. Pulman (1993:262) paraphrases it in the following way: if the left-hand side is "matched" in the logical form, the right-hand side meaning is "possible" as well, "perhaps" replacing the literal meaning "depending on the context." Hence, it is clear is that quasi-inference is not to be confused with regular inference.

$$\begin{array}{c} \boxed{0}\begin{bmatrix} \textsc{sem} & \begin{bmatrix} \textit{kicking} & \\ \textsc{agent} & \boxed{1} \\ \textsc{patient} & \boxed{2}' \end{bmatrix} \\ \textsc{morph} & \begin{bmatrix} \textsc{lem} & \text{kick} \end{bmatrix} \end{bmatrix} \\ \boxed{2}\begin{bmatrix} \textsc{sem} & \boxed{2}'\begin{bmatrix} \textit{container} \end{bmatrix} \\ \textsc{morph} & \begin{bmatrix} \textsc{lem} & \text{bucket} \\ \textsc{def} & + \\ \textsc{num} & \text{sing} \end{bmatrix} \end{bmatrix} \end{array} \Rightarrow_{\|} \begin{array}{c} \boxed{0}\begin{bmatrix} \textsc{sem} & \boxed{3}\begin{bmatrix} \textit{dying} & \\ \textsc{patient} & \boxed{1} \end{bmatrix} \\ \textsc{morph} & \begin{bmatrix} \textsc{lem} & \text{kick} \end{bmatrix} \end{bmatrix} \\ \boxed{2}\begin{bmatrix} \textsc{sem} & \boxed{3} \\ \textsc{morph} & \begin{bmatrix} \textsc{lem} & \text{bucket} \\ \textsc{def} & + \\ \textsc{num} & \text{sing} \end{bmatrix} \end{bmatrix} \end{array}$$

Figure 9 Global rewriting rule for *kick the bucket* that formalizes the quasi-inference rule in (17)

How can this be formalized? Actually, it is quite straightforward when reusing components of our lexical-semantic approach: the first step is to replace $\approx$ by $\Rightarrow_{\|}$, which is basically a rewriting rule that is defined as follows:

(18) $\quad a \Rightarrow_{\|} b \quad = \quad a \Rightarrow (a \parallel b)$

In prose, $\Rightarrow_{\|}$ takes the left-hand side (i.e., a) and wraps a $\|$-term around it with the right-hand side (i.e., b) being another $\|$-disjunct. Note that this is a very restricted, monotonic notion of term rewriting. The second step is to instantiate a and b in (18) with SEM-MORPH descriptions.

Treated in this way, the quasi-inference rule in (17) becomes the rewriting rule in figure 9, where the SEM-MORPH descriptions are directly taken from the lexical-semantic analysis in figure 3. Note that the role of Pulman's "lexical indexing," which serves to tie the quasi-inference rule to a surface string, is taken over by MORPH descriptions that are lumped together with components of SEM.

One virtue of this approach is immediately apparent: the idiomatic meaning can be condensed into one global rule, instead of flooding the lexicon with $\|$-terms. In other words, one can conceive the rewriting rule in figure 9 as a generalization over fully specified lexical entries of the lexical-ambiguity approach. Admittedly, this does not look spectacular in the example at hand, but note that this sort of rules can also be used for expressing much more generic, morphologically less fixed generalizations, for example, conceptual metaphors, and inheritance relations among those.

So far, so good. There is, however, at least one aspect of Pulman's quasi-inference approach that does not seem to fit so neatly into the picture: quasi-inference rules are applied post-syntactically and rely on the complete instantiation of the left-hand side (plus fulfillment of lexical indexing). This means that Pulman assumes a strict two-step approach: first the literal meaning is computed, and only then is the idiomatic meaning deduced. However, this is in principle incompatible with lexical-semantic approaches, where literal and idiomatic interpretations are released in parallel. Furthermore, as laid out in section 3.2 already, the two-step approach has been criticized elsewhere for contradicting psycholinguistic findings (e.g., from Cacciari & Tabossi 1988) that suggest that idioms are processed incrementally, that is, approximately word by word. This means that even partial triggers of MWEs suffice to activate the idiomatic interpretation.

For this reason, it has to be taken into consideration whether quasi-inference rules, or ||-rewriting rules, should already apply based on incomplete left-hand sides. However, the effect would be that the conjectured computational advantage of inference-based approaches would disappear, because the idiomatic interpretation would be released on a per-word basis as well – or worse: one would have to add an extra distinction in order to specify the part of the left-hand side that has to be minimally present. This is necessary because we certainly don't want to allow for unmotivated, random applications. Similarly, one has to somehow prohibit infinite regress, that is, the recursive application of an inference rule to its right-hand side.

On the other hand, one possible advantage of quasi-inference rules, at least when it comes to the treatment of conjunctive modification, could be that they cleanly separate literal and idiomatic components. However, as we argued in section 4.3, this alone would not suffice anyway because it does not explain the possible co-existence of literal and idiomatic interpretations of the same phrase. Thus, in general, no substantial gain in coverage can be attested compared to lexical-semantic approaches.

Taken together, it seems to be preferable to do syntax within a lexical-semantic approach, while expressing lexical generalizations by means of

||-rewriting rules. The latter would be part of the metagrammar, but not immediately take part in parsing. Hence, under this view, the inference-based approach supplements the lexical-ambiguity approach rather than constitutes an alternative.

6 Conclusion

The aim of this work was fourfold: (i) to promote awareness of the sort of ambiguity that can emerge when dealing with semantically idiomatic MWEs; (ii) to argue in favor of semantic ambiguity approaches on psycholinguistic and computational grounds; (iii) to sketch a lexical-semantic approach based on LTAG, which improves on the partial-function approach of Gazdar et al. (1985); (iv) to entertain the idea that the inference-based approach of Pulman (1993), under a certain formalization, should be seen as a tool to express generalizations about the morphosemantic properties of lexical entries. Sure enough, we have barely touched upon these topics, and have skipped many others. Thus, the list of objects for future work is long, the most urgent ones being the integration of partial uses and conjunctive modification, and the explication of the meaning and treatment of the ambiguity operator ||. But we hope that the underlying ideas are clear.

Some readers might still be bothered that we haven't sufficiently limited the scope of our work, remaining rather silent as to how to model morphosyntactic flexibility, or other sorts of MWEs that it is supposed to cover. We have deliberately taken a semantic stance and concentrated on non-decomposable MWEs, hoping that it's obvious that decomposable MWEs such as light-verb constructions can be dealt with as well. Sorts of non-semantic idiomaticity, as we said, were left aside and could be treated the usual, that is, phrasal, way.

As far as this work is concerned, an important motivation was to explore ways of "graceful integration" (Jackendoff 2011) of grammar models with psycholinguistic findings about the mental processing of MWEs. From our point of view, this and the question of how to account for the figurative flexibility in MWEs deserve more attention and formally more explicit models.

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Computational Coverage of Type Logical Grammar: The Montague Test

Glyn Morrill • Oriol Valentín

Abstract It is nearly half a century since Montague made his contributions to the field of logical semantics. In this time, computational linguistics has taken an almost entirely statistical turn and mainstream linguistics has adopted an almost entirely non-formal methodology. But in a minority approach reaching back before the linguistic revolution, and to the origins of computing, type logical grammar (TLG) has continued championing the flags of symbolic computation and logical rigor in discrete grammar. In this paper, we aim to concretise a measure of progress for computational grammar in the form of the *Montague Test*. This is the challenge of providing a computational cover grammar of the Montague fragment. We formulate this Montague Test and show how the challenge is met by the type logical parser/theorem-prover CatLog2.

Keywords Montague semantics · Montague grammar · categorial grammar · type logical grammar · computational grammar · semantic parsing · parsing as deduction · parsing/theorem-proving

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1 Introduction

Perhaps nobody does Montague semantics anymore, or perhaps everybody does Montague semantics now and it has become a part of the scenery. Around 1970, Richard Montague wrote three papers, "Universal grammar" (Montague 1970b), "English as a formal language" (Montague 1970a), and "The proper treatment of quantification in ordinary English" (Montague 1973), which overturned the prevailing view that natural language semantics was too ephemeral to be formalised. The third paper, especially, introduced lambda calculus and higher-order intensional logic for semantic representation by presenting a formal fragment of English with a translation into logic.

Montague's approach was first popularised in the textbook Dowty et al. 1981. Since then, linguistics has become infused with Montague semantics starting with journals such as *Linguistics and Philosophy* and conferences such as the Amsterdam Colloquium, and spreading out in such a way that today there is an extensive interdisciplinary field of formal semantics based on lambda calculus and type logic. It is not that nobody does Montague semantics anymore, it is that now Montague semantics is taken for granted by many.

If you don't know where you have come from, you don't know where you are going. How can we be sure we are making progress? Here, in relation to Montague semantics, we propose as an exercise of intermediate difficulty, as a health check on approaches, the *Montague Test*, which is to provide a computational cover grammar of the Montague fragment as represented by the example sentences of Dowty et al. 1981:chap. 7.

Our broad concern is whether linguistics, rather than building on the achievements of the past and consolidating them, is rather in danger of drifting from trend to trend or lurching from fashion to fashion, in an aleatory or even cyclic fashion. Linguistics has its scholarly roots in the arts and humanities and from such origins a certain tendency to fantasia and self-proclamation persists. Perhaps this headiness partially explains why linguistics has remained a novice science while, for example, biology and computational biology have gone from strength to strength. Our plea here is that before a linguistic approach is deamed the new revolution, it proves its credentials by providing a computational cover grammar of the 50 years old Montague fragment.

In providing a computational cover grammar, we semantically parse the sentences provided with analysis trees in Dowty et al. 1981:chap. 7, assigning them logical translations "corresponding" to those given there, and distinguishing the same readings with comparable truth conditions. This minicorpus, which includes quantification, intensionality and some coordination and anaphora, is as follows:[1]

(7-7) **John walks** $walk'(j)$

[1]The reference numbers are taken directly from Dowty et al. 1981:chap. 7. Observe that the minicorpus preserves Montague's practice of assigning raised types to extensional verbs for uniformity with intensional verbs.

(7-16) **every man talks** $\forall x[man'(x) \to talk'(x)]$

(7-19) **the fish walks** $\exists y[\forall x[fish'(x) \leftrightarrow x = y] \wedge walk'(y)]$

(7-32) **every man walks or talks** $\forall y[man'(y) \to [walk'(y) \vee talk'(y)]]$

(7-34) **every man walks or every man talks**
$[\forall x[man'(x) \to walk'(x)] \vee \forall x[man'(x) \to talk'(x)]]$

(7-39) **a woman walks and she talks**
$\exists x[woman'(x) \wedge [walk'(x) \wedge talk'(x)]]$

(7-43, 45) **John believes that a fish walks**
$believe'(j, {}^\wedge\exists x[fish'(x) \wedge walk'(x)])$
$\exists x[fish'(x) \wedge believe'(j, {}^\wedge[walk'(x)])]$

(7-48, 49, 52) **every man believes that a fish walks**
$\exists x[fish'(x) \wedge \forall y[man'(y) \to believe'(y, {}^\wedge[walk'(x)])]]$
$\forall y[man'(y) \to \exists x[fish'(x) \wedge believe'(y, {}^\wedge[walk'(x)])]]$
$\forall y[man'(y) \to believe'(y, {}^\wedge[\exists x[fish'(x) \wedge walk'(x)]])]$

(7-57) **every fish such that it walks talks**
$\forall x[[fish'(x) \wedge walk'(x)] \to talk'(x)]$

(7-60, 62) **John seeks a unicorn**
$try'(j, {}^\wedge[find'({}^\wedge\lambda P\exists x[unicorn'(x) \wedge [{}^\vee P](x)])])$
$try'(j, {}^\wedge\lambda z[\exists x[unicorn'(x) \wedge [find'({}^\wedge\lambda P[[{}^\vee P](z)])(j)]]])$

(7-73) **John is Bill** $j = b$

(7-76) **John is a man** $man'(j)$

(7-83) **necessarily John walks** $\Box[walk'(j)]$

(7-86) **John walks slowly** $slowly'({}^\wedge walk')(j)$

(7-91) **John tries to walk** $try'({}^\wedge walk')(j)$

(7-94) **John tries to catch a fish and eat it**
$try'(j, {}^\wedge\lambda y\exists x[fish'(x) \wedge$
$[catch'({}^\wedge\lambda P[[{}^\vee P](y)])(x)) \wedge eat'({}^\wedge\lambda P[[{}^\vee P](y)])(x))]])$

	cont. mult.	disc. mult.	add.	qu.	norm. mod.	brack. mod.	exp.	limited contr. & weak.
primary	$/$ $\backslash$ $\bullet$ I	$\uparrow$ $\downarrow$ $\odot$ J	$\&$ $\oplus$	$\bigwedge$ $\bigvee$	$\Box$ $\Diamond$	$[\,]^{-1}$ $\langle\rangle$	$!$ $?$	$\vert$ W
sem. inactive variants	$\bullet\!\!-$ $-\!\!\circ$ $\circ\!\!-$ $-\!\!\bullet$ ◐ ◑	$\overset{\bullet}{\uparrow}$ $\underset{\circ}{\downarrow}$ $\overset{\circ}{\uparrow}$ $\underset{\bullet}{\downarrow}$ ◓ ◒	$\sqcap$ $\sqcup$	$\forall$ $\exists$	$\blacksquare$ $\blacklozenge$			
det. synth.	$\triangleleft^{-1}$ $\triangleright^{-1}$ $\triangleleft$ $\triangleright$	$\check{}$ $\hat{}$						diff.
nondet. synth.	$\div$ $\circ$	$\triangleq$ $\veebar$ $\diamond$						$-$

Table 1 Categorial connectives

(7-98) **John finds a unicorn**

$\exists x[unicorn'(x) \wedge [find'(^\wedge\lambda P[[^\vee P](x)])(j)]]$

(7-105) **every man such that he loves a woman loses her**

$\exists y[woman'(y) \wedge \forall x[[man'(x) \wedge love'(^\wedge\lambda P([[^\vee P](y)])(x)] \to$
$lose'(^\wedge\lambda P([[^\vee P](y)])(x)]]$

(7-110) **John walks in a park**

$\exists x[park'(x) \wedge in'(^\wedge\lambda P[[^\vee P](x)])(^\wedge walk')(j)]$

(7-116, 118) **every man doesn't walk**

$\neg\forall x[man'(x) \to walk'(x)]$
$\forall x[man'(x) \to \neg walk'(x)]$

2 Type Logical Grammar

Type logical grammar (TLG) is a categorial theory of syntax and semantics in which words and expressions are classified by logical types. TLG is expounded in Moortgat 1988, 1997, Morrill 1994, 2011, Carpenter 1997, Jäger 2005, Moot & Retoré 2012. The logical types form an intuitionistic sublinear logic and their rules are universal; a grammar comprises just a lexicon classifying basic expressions. TLG is thus a purely lexical formalism.

A *sign* $\alpha\colon A\colon \phi$ consists of a *prosodic form* α, a *syntactic type* A, and a *semantic form* ϕ. A *prosodic sort map* s maps syntactic types to prosodic sorts which are the number of points of discontinuity of expressions of that type; a *semantic type map* T maps syntactic types to semantic types which are essentially formulas of intuitionistic propositional logic/types of lambda calculus under the Curry-Howard correspondence. In a sign $\alpha\colon A\colon \phi$, α must be of prosodic sort $s(A)$ and ϕ must be of semantic type $T(A)$.

The categorial connectives of our type logical grammar are as shown in table 1. They comprise the primary connectives, in the first row, semantically inactive variants, in the second row, and deterministic (unary) and nondeterministic (binary) defined connectives in the third and fourth rows.

Regarding the primary connectives, the displacement connectives (Morrill et al. 2011) are made up of the continuous (Lambek) and discontinuous multiplicatives. Then there are additives (Morrill 1990a), quantifiers (Morrill 1994), normal modalities (Morrill 1990b, Moortgat 1997), bracket modalities (Morrill 1992, Moortgat 1996), exponentials (Morrill & Valentín 2015a), limited contraction (Jäger 2005) and limited weakening (Morrill & Valentín 2014b).

The semantically inactive secondary connectives are made up of semantically inactive multiplicatives (Morrill & Valentín 2014b), additives (Morrill 1994), quantifiers (Morrill 1994), and normal modalities (Hepple 1990, Moortgat 1997). The deterministic secondary connectives are made up of the unary connectives projection and injection (Morrill et al. 2009) and split and bridge (Morrill & Merenciano 1996), and the nondeterministic secondary connectives are made up of concatenative binary connectives of division and product and discontinuous binary connectives of extraction, infixation and product (Morrill et al. 2011). At the bottom right is a metalogical ("negation as failure") connective of difference (Morrill & Valentín 2014a).

A lexicon consists of a set of (lexical) signs. Our lexicon for the Montague fragment is as follows; rules for connectives used in the fragment are given in the Appendix:

a : $\blacksquare\forall g(\forall f((Sf{\uparrow}\blacksquare Nt(s(g))){\downarrow}Sf)/CNs(g))$: $\lambda A\lambda B\exists C[(A\ C) \wedge (B\ C)]$
and : $\blacksquare\forall f((\blacksquare ?Sf\backslash[]^{-1}[]^{-1}Sf)/\blacksquare Sf)$: $(\Phi^{n+}\ o\ and)$
and : $\blacksquare\forall a\forall f((\blacksquare ?(\langle\rangle Na\backslash Sf)\backslash[]^{-1}[]^{-1}(\langle\rangle Na\backslash Sf))/\blacksquare(\langle\rangle Na\backslash Sf))$: $(\Phi^{n+}\ (s\ o)\ and)$
believes : $\Box((\langle\rangle\exists gNt(s(g))\backslash Sf)/(CPthat\sqcup\Box Sf))$: $\hat{}\lambda A\lambda B((\check{}believe\ A)\ B)$
bill : $\blacksquare Nt(s(m))$: b
catch : $\Box((\langle\rangle\exists aNa\backslash Sb)/\exists aNa)$: $\hat{}\lambda A\lambda B((\check{}catch\ A)\ B)$
doesnt : $\blacksquare\forall g\forall a((Sg{\uparrow}((\langle\rangle Na\backslash Sf)/(\langle\rangle Na\backslash Sb))){\downarrow}Sg)$: $\lambda A\neg(A\ \lambda B\lambda C(B\ C))$
eat : $\Box((\langle\rangle\exists aNa\backslash Sb)/\exists aNa)$: $\hat{}\lambda A\lambda B((\check{}eat\ A)\ B)$
every : $\blacksquare\forall g(\forall f((Sf{\uparrow}Nt(s(g))){\downarrow}Sf)/CNs(g))$: $\lambda A\lambda B\forall C[(A\ C) \rightarrow (B\ C)]$
finds : $\Box((\langle\rangle\exists gNt(s(g))\backslash Sf)/\exists aNa)$: $\hat{}\lambda A\lambda B((\check{}find\ A)\ B)$
fish : $\Box CNs(n)$: $fish$
he : $\blacksquare[]^{-1}\forall g((\blacksquare Sg|\blacksquare Nt(s(m)))/(\langle\rangle Nt(s(m))\backslash Sg))$: λAA
her : $\blacksquare\forall g\forall a(((\langle\rangle Na\backslash Sg){\uparrow}\blacksquare Nt(s(f))){\downarrow}(\blacksquare(\langle\rangle Na\backslash Sg)|\blacksquare Nt(s(f))))$: λAA
in : $\Box(\forall a\forall f((\langle\rangle Na\backslash Sf)\backslash(\langle\rangle Na\backslash Sf))/\exists aNa)$: $\hat{}\lambda A\lambda B\lambda C((\check{}in\ A)\ (B\ C))$
is : $\blacksquare((\langle\rangle\exists gNt(s(g))\backslash Sf)/(\exists aNa\oplus(\exists g((CNg/CNg)\sqcup(CNg\backslash CNg))-I)))$: $\lambda A\lambda B(A \rightarrow C.[B = C]; D.((D\ \lambda E[E = B])\ B))$
it : $\blacksquare\forall f\forall a(((\langle\rangle Na\backslash Sf){\uparrow}\blacksquare Nt(s(n))){\downarrow}(\blacksquare(\langle\rangle Na\backslash Sf)|\blacksquare Nt(s(n))))$: λAA
it : $\blacksquare[]^{-1}\forall f((\blacksquare Sf|\blacksquare Nt(s(n)))/(\langle\rangle Nt(s(n))\backslash Sf))$: λAA
john : $\blacksquare Nt(s(m))$: j
loses : $\Box((\langle\rangle\exists gNt(s(g))\backslash Sf)/\exists aNa)$: $\hat{}\lambda A\lambda B((\check{}lose\ A)\ B)$
loves : $\Box((\langle\rangle\exists gNt(s(g))\backslash Sf)/\exists aNa)$: $\hat{}\lambda A\lambda B((\check{}love\ A)\ B)$
man : $\Box CNs(m)$: man
necessarily : $\blacksquare(SA/\Box SA)$: Nec
or : $\blacksquare\forall f((\blacksquare ?Sf\backslash[]^{-1}[]^{-1}Sf)/\blacksquare Sf)$: $(\Phi^{n+}\ o\ or)$
or : $\blacksquare\forall a\forall f((\blacksquare ?(\langle\rangle Na\backslash Sf)\backslash[]^{-1}[]^{-1}(\langle\rangle Na\backslash Sf))/\blacksquare(\langle\rangle Na\backslash Sf))$: $(\Phi^{n+}\ (s\ o)\ or)$
or : $\blacksquare\forall f((\blacksquare ?(Sf/(\langle\rangle\exists gNt(s(g))\backslash Sf))\backslash[]^{-1}[]^{-1}(Sf/(\langle\rangle\exists gNt(s(g))\backslash Sf)))/\blacksquare(Sf/(\langle\rangle\exists gNt(s(g))\backslash Sf)))$: $(\Phi^{n+}\ (s\ o)\ or)$
park : $\Box CNs(n)$: $park$
seeks : $\Box((\langle\rangle\exists gNt(s(g))\backslash Sf)/\Box\forall a\forall f(((Na\backslash Sf)/\exists bNb)\backslash(Na\backslash Sf)))$: $\hat{}\lambda A\lambda B((\check{}try\ \hat{}((\check{}A\ \check{}find)\ B))\ B)$
she : $\blacksquare[]^{-1}\forall g((\blacksquare Sg|\blacksquare Nt(s(f)))/(\langle\rangle Nt(s(f))\backslash Sg))$: λAA

slowly : $\Box\forall a\forall f(\Box(\langle\rangle Na\backslash Sf)\backslash(\langle\rangle\Box Na\backslash Sf))$: $\hat{}\lambda A\lambda B(\check{}slowly\ \hat{}(\check{}A\ \check{}B))$
such+that : $\blacksquare\forall n((CNn\backslash CNn)/(Sf|\blacksquare Nt(n)))$: $\lambda A\lambda B\lambda C[(B\ C)\wedge(A\ C)]$
talks : $\Box(\langle\rangle\exists gNt(s(g))\backslash Sf)$: $\hat{}\lambda A(\check{}talk\ A)$
that : $\blacksquare(CPthat/\Box Sf)$: λAA
the : $\blacksquare\forall n(Nt(n)/CNn)$: ι
to : $\blacksquare((PPto/\exists aNa)\sqcap\forall n((\langle\rangle Nn\backslash Si)/(\langle\rangle Nn\backslash Sb)))$: λAA
tries : $\Box((\langle\rangle\exists gNt(s(g))\backslash Sf)/\Box(\langle\rangle\exists gNt(s(g))\backslash Si))$:
$\hat{}\lambda A\lambda B((\check{}try\ \hat{}(\check{}A\ B))\ B)$
unicorn : $\Box CNs(n)$: *unicorn*
walk : $\Box(\langle\rangle\exists aNa\backslash Sb)$: $\hat{}\lambda A(\check{}walk\ A)$
walks : $\Box(\langle\rangle\exists gNt(s(g))\backslash Sf)$: $\hat{}\lambda A(\check{}walk\ A)$
woman : $\Box CNs(f)$: *woman*

3 Performing the Montague Test

CatLog2 is a type logical parser/theorem prover with a web interface at `http://www.cs.upc.edu/~morrill/CatLog/CatLog2/index.php`. It:

- comprises 6000 lines of prolog
- has 20 primitive categorial connectives, 29 defined connectives, and 1 metalogical connective: a total of 50 connectives
- has typically 2 rules for each connective: a rule of use and a rule of proof: roughly $50 \times 2 = 100$ rules
- uses backward chaining sequent proof search and uses *focusing* (Andreoli 1992); for the focused rules—about half of them—for a binary connective there are 4 cases of "polarity": $+/+$, $+/-$, $-/+$, $-/-$: $50 + 50 \times 4 =$ a total of about 250 rules

At CSSP in Paris on 9 October 2015, the Montague Test was performed by CatLog2 version "gmontague" with input in the following format; note that currently it is necessary to give syntactic domains in the input to CatLog2 (though these play no role in Montague's grammar):

str(dwp('(7-7)'), [b([john]), walks], s(f)).
str(dwp('(7-16)'), [b([every, man]), talks], s(f)).
str(dwp('(7-19)'), [b([the, fish]), walks], s(f)).
str(dwp('(7-32)'), [b([every, man]), b([b([walks, or, talks])])], s(f)).

str(dwp('(7-34)'), [b([b([b([every, man]), walks, or, b([every, man]), talks])])], s(f)).
str(dwp('(7-39)'), [b([b([b([a, woman]), walks, and, b([she]), talks])])], s(f)).
str(dwp('(7-43, 45)'), [b([john]), believes, that, b([a, fish]), walks], s(f)).
str(dwp('(7-48, 49, 52)'), [b([every, man]), believes, that, b([a, fish]), walks], s(f)).
str(dwp('(7-57)'), [b([every, fish, such, that, b([it]), walks]), talks], s(f)).
str(dwp('(7-60, 62)'), [b([john]), seeks, a, unicorn], s(f)).
str(dwp('(7-73)'), [b([john]), is, bill], s(f)).
str(dwp('(7-76)'), [b([john]), is, a, man], s(f)).
str(dwp('(7-83)'), [necessarily, b([john]), walks], s(f)).
str(dwp('(7-86)'), [b([john]), walks, slowly], s(f)).
str(dwp('(7-91)'), [b([john]), tries, to, walk], s(f)).
str(dwp('(7-94)'), [b([john]), tries, to, b([b([catch, a, fish, and, eat, it])])], s(f)).
str(dwp('(7-98)'), [b([john]), finds, a, unicorn], s(f)).
str(dwp('(7-105)'), [b([every, man, such, that, b([he]), loves, a, woman]), loses, her], s(f)).
str(dwp('(7-110)'), [b([john]), walks, in, a, park], s(f)).
str(dwp('(7-116, 118)'), [b([every, man]), doesnt, walk], s(f)).

The LaTeX output generated was as follows. Each item comes in the form of its identifier and the prosodic form of its input, followed by each semantically labelled sequent that results from lexical lookup. Where there is a derivation or derivations for a sequent, these appear in figures with the semantic forms delivered by the analysis in the main text. CatLog2 observes the proof search discipline of *focusing* (Andreoli 1992, Morrill & Valentín 2015b): in the derivations the focused types are boxed, which means that when a complex type in a conclusion is boxed, it is the active type of the inference. For reasons of space, some derivations are omitted.

(dwp((7-7))) [**john**]+**walks** : Sf

$$[\blacksquare Nt(s(m)) : j], \square(\langle\rangle\exists g Nt(s(g))\backslash Sf) : \hat{}\lambda A(\check{}walk\ A) \ \Rightarrow\ Sf$$

$$\dfrac{\dfrac{\dfrac{\dfrac{\dfrac{}{\boxed{Nt(s(m))} \Rightarrow Nt(s(m))}}{\boxed{\blacksquare Nt(s(m))} \Rightarrow Nt(s(m))}\blacksquare L}{\blacksquare Nt(s(m)) \Rightarrow \boxed{\exists g Nt(s(g))}}\exists R}{[\blacksquare Nt(s(m))] \Rightarrow \boxed{\langle\rangle \exists g Nt(s(g))}}\langle\rangle R \qquad \dfrac{}{\boxed{Sf} \Rightarrow Sf}}{\dfrac{[\blacksquare Nt(s(m))], \boxed{\langle\rangle \exists g Nt(s(g)) \backslash Sf} \Rightarrow Sf}{[\blacksquare Nt(s(m))], \boxed{\Box(\langle\rangle \exists g Nt(s(g)) \backslash Sf)} \Rightarrow Sf}\Box L}\backslash L$$

Figure 1 Derivation of (dwp((7-7)))

For the derivation, see figure 1.

$({}^{\vee}walk\ j)$

(dwp((7-16))) [**every**+**man**]+**talks** : Sf

$[\blacksquare\forall g(\forall f((Sf{\uparrow}Nt(s(g))){\downarrow}Sf)/CNs(g)) : \lambda A\lambda B\forall C[(A\ C) \rightarrow (B\ C)],$
$\Box CNs(m) : man], \Box(\langle\rangle\exists g Nt(s(g))\backslash Sf) : {}^{\wedge}\lambda D({}^{\vee}talk\ D) \Rightarrow Sf$

For the derivation, see figure 2.

$\forall C[({}^{\vee}man\ C) \rightarrow ({}^{\vee}talk\ C)]$

(dwp((7-19))) [**the**+**fish**]+**walks** : Sf

$[\blacksquare\forall n(Nt(n)/CNn) : \iota, \Box CNs(n) : fish], \Box(\langle\rangle\exists g Nt(s(g))\backslash Sf) :$
${}^{\wedge}\lambda A({}^{\vee}walk\ A) \Rightarrow Sf$

(Derivation omitted)

$({}^{\vee}walk\ (\iota\ {}^{\vee}fish))$

(dwp((7-32))) [**every**+**man**]+[[**walks**+**or**+**talks**]] : Sf

$[\blacksquare\forall g(\forall f((Sf{\uparrow}Nt(s(g))){\downarrow}Sf)/CNs(g)) : \lambda A\lambda B\forall C[(A\ C) \rightarrow (B\ C)],$
$\Box CNs(m) : man], [[\Box(\langle\rangle\exists g Nt(s(g))\backslash Sf) : {}^{\wedge}\lambda D({}^{\vee}walk\ D),$
$\blacksquare\forall f((\blacksquare ?Sf\backslash[]^{-1}[]^{-1}Sf)/\blacksquare Sf) : (\Phi^{n+}\ o\ or), \Box(\langle\rangle\exists g Nt(s(g))\backslash Sf) :$
${}^{\wedge}\lambda E({}^{\vee}talk\ E)]] \Rightarrow Sf$

$$
\AxiomC{}
\UnaryInfC{$Nt(s(m)) \Rightarrow Nt(s(m))$}
\RightLabel{$\exists R$}
\UnaryInfC{$Nt(s(m)) \Rightarrow \boxed{\exists g Nt(s(g))}$}
\RightLabel{$\langle\rangle R$}
\UnaryInfC{$[Nt(s(m))] \Rightarrow \boxed{\langle\rangle\exists g Nt(s(g))}$}
\AxiomC{}
\UnaryInfC{$\boxed{Sf} \Rightarrow Sf$}
\RightLabel{$\backslash L$}
\BinaryInfC{$[Nt(s(m))], \boxed{\langle\rangle\exists g Nt(s(g))\backslash Sf} \Rightarrow Sf$}
\RightLabel{$\Box L$}
\UnaryInfC{$[Nt(s(m))], \boxed{\Box(\langle\rangle\exists g Nt(s(g))\backslash Sf)} \Rightarrow Sf$}
\RightLabel{$\uparrow R$}
\UnaryInfC{$[1], \Box(\langle\rangle\exists g Nt(s(g))\backslash Sf) \Rightarrow Sf{\uparrow}Nt(s(m))$}
\AxiomC{}
\UnaryInfC{$\boxed{Sf} \Rightarrow Sf$}
\RightLabel{$\downarrow L$}
\BinaryInfC{$[\boxed{(Sf{\uparrow}Nt(s(m))){\downarrow}Sf}], \Box(\langle\rangle\exists g Nt(s(g))\backslash Sf) \Rightarrow Sf$}
\RightLabel{$\forall L$}
\UnaryInfC{$[\boxed{\forall f((Sf{\uparrow}Nt(s(m))){\downarrow}Sf)}], \Box(\langle\rangle\exists g Nt(s(g))\backslash Sf) \Rightarrow Sf$}
\AxiomC{}
\UnaryInfC{$\boxed{CNs(m)} \Rightarrow CNs(m)$}
\RightLabel{$\Box L$}
\UnaryInfC{$\boxed{\Box CNs(m)} \Rightarrow CNs(m)$}
\RightLabel{$/L$}
\BinaryInfC{$[\boxed{\forall f((Sf{\uparrow}Nt(s(m))){\downarrow}Sf)/CNs(m)}, \Box CNs(m)], \Box(\langle\rangle\exists g Nt(s(g))\backslash Sf) \Rightarrow Sf$}
\RightLabel{$\forall L$}
\UnaryInfC{$[\boxed{\forall g(\forall f((Sf{\uparrow}Nt(s(g))){\downarrow}Sf)/CNs(g))}, \Box CNs(m)], \Box(\langle\rangle\exists g Nt(s(g))\backslash Sf) \Rightarrow Sf$}
\RightLabel{$\blacksquare L$}
\UnaryInfC{$[\boxed{\blacksquare\forall g(\forall f((Sf{\uparrow}Nt(s(g))){\downarrow}Sf)/CNs(g))}, \Box CNs(m)], \Box(\langle\rangle\exists g Nt(s(g))\backslash Sf) \Rightarrow Sf$}
\DisplayProof
$$

Figure 2 Derivation of (dwp((7-16)))

$[\blacksquare\forall g(\forall f((Sf{\uparrow}Nt(s(g))){\downarrow}Sf)/CNs(g)) : \lambda A\lambda B\forall C[(A\ C) \to (B\ C)],$
$\Box CNs(m) : man], [[\Box(\langle\rangle\exists g Nt(s(g))\backslash Sf) : {}^\wedge\lambda D({}^\vee walk\ D),$
$\blacksquare\forall a\forall f((\blacksquare?(\langle\rangle Na\backslash Sf)\backslash[]^{-1}[]^{-1}(\langle\rangle Na\backslash Sf))/\blacksquare(\langle\rangle Na\backslash Sf)) : (\Phi^{n+}\ (s\ o)\ or),$
$\Box(\langle\rangle\exists g Nt(s(g))\backslash Sf) : {}^\wedge\lambda E({}^\vee talk\ E)]] \Rightarrow Sf$

(Derivation omitted)

$\forall C[({}^\vee man\ C) \to [({}^\vee walk\ C) \vee ({}^\vee talk\ C)]]$

$[\blacksquare\forall g(\forall f((Sf{\uparrow}Nt(s(g))){\downarrow}Sf)/CNs(g)) : \lambda A\lambda B\forall C[(A\ C) \to (B\ C)],$
$\Box CNs(m) : man], [[\Box(\langle\rangle\exists g Nt(s(g))\backslash Sf) : {}^\wedge\lambda D({}^\vee walk\ D),$
$\blacksquare\forall f((\blacksquare?(Sf/(\langle\rangle\exists g Nt(s(g))\backslash Sf))\backslash[]^{-1}[]^{-1}(Sf/(\langle\rangle\exists g Nt(s(g))\backslash Sf)))/$
$\blacksquare(Sf/(\langle\rangle\exists g Nt(s(g))\backslash Sf))) : (\Phi^{n+}\ (s\ o)\ or), \Box(\langle\rangle\exists g Nt(s(g))\backslash Sf) :$
${}^\wedge\lambda E({}^\vee talk\ E)]] \Rightarrow Sf$

(dwp((7-34))) [[[**every**+**man**]+**walks**+**or**+[**every**+**man**]+**talks**]] : Sf

$[[[\blacksquare\forall g(\forall f((Sf{\uparrow}Nt(s(g))){\downarrow}Sf)/CNs(g)) : \lambda A\lambda B\forall C[(A\ C) \to (B\ C)],$
$\Box CNs(m) : man], \Box(\langle\rangle\exists g Nt(s(g))\backslash Sf) : {}^\wedge\lambda D({}^\vee walk\ D),$
$\blacksquare\forall f((\blacksquare?Sf\backslash[]^{-1}[]^{-1}Sf)/\blacksquare Sf) : (\Phi^{n+}\ o\ or),$
$[\blacksquare\forall g(\forall f((Sf{\uparrow}Nt(s(g))){\downarrow}Sf)/CNs(g)) : \lambda E\lambda F\forall G[(E\ G) \to (F\ G)],$
$\Box CNs(m) : man], \Box(\langle\rangle\exists g Nt(s(g))\backslash Sf) : {}^\wedge\lambda H({}^\vee talk\ H)]] \Rightarrow Sf$

(Derivation omitted)

$[\forall H[(\check{}man\ H) \to (\check{}walk\ H)] \vee \forall C[(\check{}man\ C) \to (\check{}talk\ C)]]$

$[[[\blacksquare\forall g(\forall f((Sf{\uparrow}Nt(s(g))){\downarrow}Sf)/CNs(g)) : \lambda A\lambda B\forall C[(A\ C) \to (B\ C)],$
$\square CNs(m) : man], \square(\langle\rangle\exists gNt(s(g))\backslash Sf) : \hat{}\lambda D(\check{}walk\ D),$
$\blacksquare\forall a\forall f((\blacksquare?(\langle\rangle Na\backslash Sf)\backslash[]^{-1}[]^{-1}(\langle\rangle Na\backslash Sf))/\blacksquare(\langle\rangle Na\backslash Sf)) : (\Phi^{n+}\ (s\ o)\ or),$
$[\blacksquare\forall g(\forall f((Sf{\uparrow}Nt(s(g))){\downarrow}Sf)/CNs(g)) : \lambda E\lambda F\forall G[(E\ G) \to (F\ G)],$
$\square CNs(m) : man], \square(\langle\rangle\exists gNt(s(g))\backslash Sf) : \hat{}\lambda H(\check{}talk\ H)]] \ \Rightarrow\ Sf$

$[[[\blacksquare\forall g(\forall f((Sf{\uparrow}Nt(s(g))){\downarrow}Sf)/CNs(g)) : \lambda A\lambda B\forall C[(A\ C) \to (B\ C)],$
$\square CNs(m) : man], \square(\langle\rangle\exists gNt(s(g))\backslash Sf) : \hat{}\lambda D(\check{}walk\ D),$
$\blacksquare\forall f((\blacksquare?(Sf/(\langle\rangle\exists gNt(s(g))\backslash Sf))\backslash[]^{-1}[]^{-1}(Sf/(\langle\rangle\exists gNt(s(g))\backslash Sf)))/$
$\blacksquare(Sf/(\langle\rangle\exists gNt(s(g))\backslash Sf))) : (\Phi^{n+}\ (s\ o)\ or),$
$[\blacksquare\forall g(\forall f((Sf{\uparrow}Nt(s(g))){\downarrow}Sf)/CNs(g)) : \lambda E\lambda F\forall G[(E\ G) \to (F\ G)],$
$\square CNs(m) : man], \square(\langle\rangle\exists gNt(s(g))\backslash Sf) : \hat{}\lambda H(\check{}talk\ H)]] \ \Rightarrow\ Sf$

(dwp((7-39))) [[[**a**+**woman**]+**walks**+**and**+[**she**]+**talks**]] : Sf

$[[[\blacksquare\forall g(\forall f((Sf{\uparrow}\blacksquare Nt(s(g))){\downarrow}Sf)/CNs(g)) : \lambda A\lambda B\exists C[(A\ C) \wedge (B\ C)],$
$\square CNs(f) : woman], \square(\langle\rangle\exists gNt(s(g))\backslash Sf) : \hat{}\lambda D(\check{}walk\ D),$
$\blacksquare\forall f((\blacksquare?Sf\backslash[]^{-1}[]^{-1}Sf)/\blacksquare Sf) : (\Phi^{n+}\ o\ and),$
$[\blacksquare[]^{-1}\forall g((\blacksquare Sg|\blacksquare Nt(s(f)))/(\langle\rangle Nt(s(f))\backslash Sg)) : \lambda EE],$
$\square(\langle\rangle\exists gNt(s(g))\backslash Sf) : \hat{}\lambda F(\check{}talk\ F)]] \ \Rightarrow\ Sf$

(Derivation omitted)

$\exists C[(\check{}woman\ C) \wedge [(\check{}walk\ C) \wedge (\check{}talk\ C)]]$

$[[[\blacksquare\forall g(\forall f((Sf{\uparrow}\blacksquare Nt(s(g))){\downarrow}Sf)/CNs(g)) : \lambda A\lambda B\exists C[(A\ C) \wedge (B\ C)],$
$\square CNs(f) : woman], \square(\langle\rangle\exists gNt(s(g))\backslash Sf) : \hat{}\lambda D(\check{}walk\ D),$
$\blacksquare\forall a\forall f((\blacksquare?(\langle\rangle Na\backslash Sf)\backslash[]^{-1}[]^{-1}(\langle\rangle Na\backslash Sf))/\blacksquare(\langle\rangle Na\backslash Sf)) :$
$(\Phi^{n+}\ (s\ o)\ and),$
$[\blacksquare[]^{-1}\forall g((\blacksquare Sg|\blacksquare Nt(s(f)))/(\langle\rangle Nt(s(f))\backslash Sg)) : \lambda EE],$
$\square(\langle\rangle\exists gNt(s(g))\backslash Sf) : \hat{}\lambda F(\check{}talk\ F)]] \ \Rightarrow\ Sf$

(dwp((7-43, 45))) [**john**]+**believes**+**that**+[**a**+**fish**]+**walks** : Sf

$[\blacksquare Nt(s(m)) : j], \square((\langle\rangle\exists gNt(s(g))\backslash Sf)/(CPthat\sqcup\square Sf)) :$
$\hat{}\lambda A\lambda B((\check{}believe\ A)\ B), \blacksquare(CPthat/\square Sf) : \lambda CC,$

$[\blacksquare\forall g(\forall f((Sf{\uparrow}\blacksquare Nt(s(g))){\downarrow}Sf)/CNs(g)) : \lambda D\lambda E\exists F[(D\ F) \wedge (E\ F)],$
$\square CNs(n) : fish], \square(\langle\rangle\exists gNt(s(g))\backslash Sf) : \hat{}\lambda G(\check{}walk\ G) \ \Rightarrow\ Sf$

For the derivation, see figure 3.

$\exists C[(\check{}fish\ C) \wedge ((\check{}believe\ \hat{}(\check{}walk\ C))\ j)]$

For the derivation, see figure 4.

$((\check{}believe\ \hat{}\exists F[(\check{}fish\ F) \wedge (\check{}walk\ F))])\ j)$

(dwp((7-48, 49, 52))) [**every**+**man**]+**believes**+**that**+[**a**+**fish**]+**walks** : Sf

$[\blacksquare\forall g(\forall f((Sf{\uparrow}Nt(s(g))){\downarrow}Sf)/CNs(g)) : \lambda A\lambda B\forall C[(A\ C) \rightarrow (B\ C)],$
$\square CNs(m) : man], \square((\langle\rangle\exists gNt(s(g))\backslash Sf)/(CPthat\sqcup\square Sf)) :$
$\hat{}\lambda D\lambda E((\check{}believe\ D)\ E), \blacksquare(CPthat/\square Sf) : \lambda FF,$
$[\blacksquare\forall g(\forall f((Sf{\uparrow}\blacksquare Nt(s(g))){\downarrow}Sf)/CNs(g)) : \lambda G\lambda H\exists I[(G\ I) \wedge (H\ I)],$
$\square CNs(n) : fish], \square(\langle\rangle\exists gNt(s(g))\backslash Sf) : \hat{}\lambda J(\check{}walk\ J) \ \Rightarrow\ Sf$

(Derivation omitted)

$\exists C[(\check{}fish\ C) \wedge \forall G[(\check{}man\ G) \rightarrow ((\check{}believe\ \hat{}(\check{}walk\ C))\ G)]]$

(Derivation omitted)

$\forall C[(\check{}man\ C) \rightarrow \exists G[(\check{}fish\ G) \wedge ((\check{}believe\ \hat{}(\check{}walk\ G))\ C)]]$

(Derivation omitted)

$\forall C[(\check{}man\ C) \rightarrow ((\check{}believe\ \hat{}\exists J[(\check{}fish\ J) \wedge (\check{}walk\ J)])\ C)]$

(dwp((7-57))) [**every**+**fish**+**such**+**that**+[**it**]+**walks**]+**talks** : Sf

$[\blacksquare\forall g(\forall f((Sf{\uparrow}Nt(s(g))){\downarrow}Sf)/CNs(g)) : \lambda A\lambda B\forall C[(A\ C) \rightarrow (B\ C)],$
$\square CNs(n) : fish, \blacksquare\forall n((CNn\backslash CNn)/(Sf|\blacksquare Nt(n))) : \lambda D\lambda E\lambda F[(E\ F) \wedge (D\ F)],$
$[\blacksquare\forall f\forall a(((\langle\rangle Na\backslash Sf){\uparrow}\blacksquare Nt(s(n))){\downarrow}(\blacksquare(\langle\rangle Na\backslash Sf)|\blacksquare Nt(s(n)))) : \lambda GG],$
$\square(\langle\rangle\exists gNt(s(g))\backslash Sf) : \hat{}\lambda H(\check{}walk\ H)], \square(\langle\rangle\exists gNt(s(g))\backslash Sf) :$
$\hat{}\lambda I(\check{}talk\ I) \ \Rightarrow\ Sf$

$[\blacksquare\forall g(\forall f((Sf{\uparrow}Nt(s(g))){\downarrow}Sf)/CNs(g)) : \lambda A\lambda B\forall C[(A\ C) \rightarrow (B\ C)],$
$\square CNs(n) : fish, \blacksquare\forall n((CNn\backslash CNn)/(Sf|\blacksquare Nt(n))) : \lambda D\lambda E\lambda F[(E\ F) \wedge (D\ F)],$
$[\blacksquare[]^{-1}\forall f((\blacksquare Sf|\blacksquare Nt(s(n)))/(\langle\rangle Nt(s(n))\backslash Sf)) : \lambda GG],$

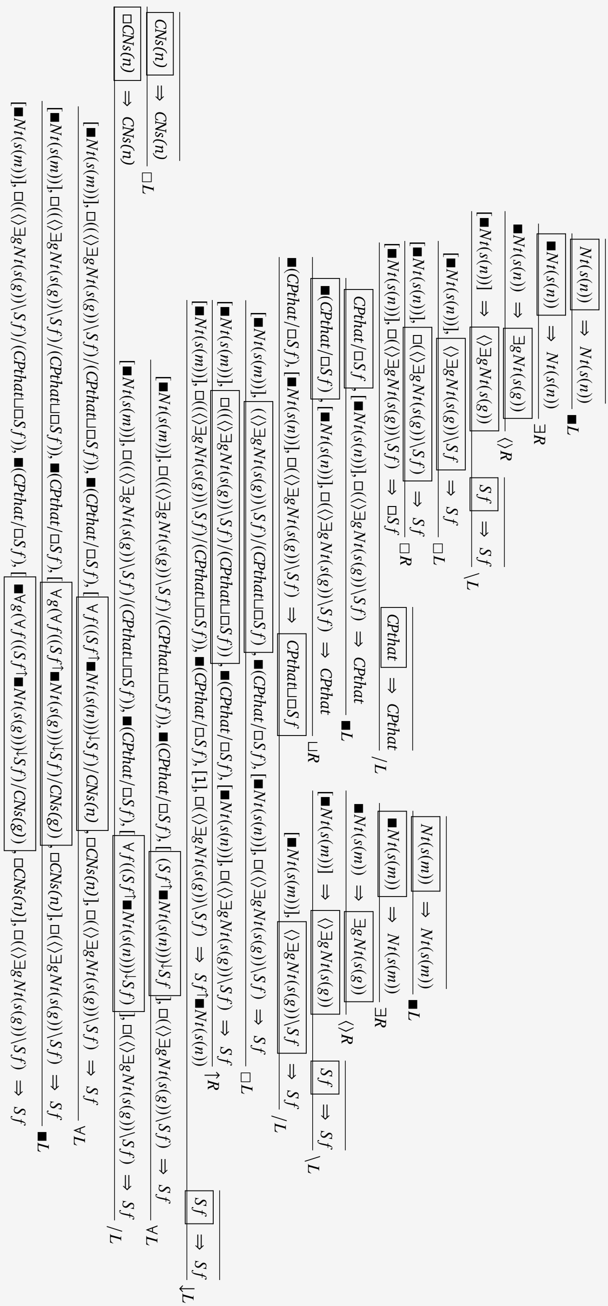

Figure 3 First derivation of (dwp((7-43, 45)))

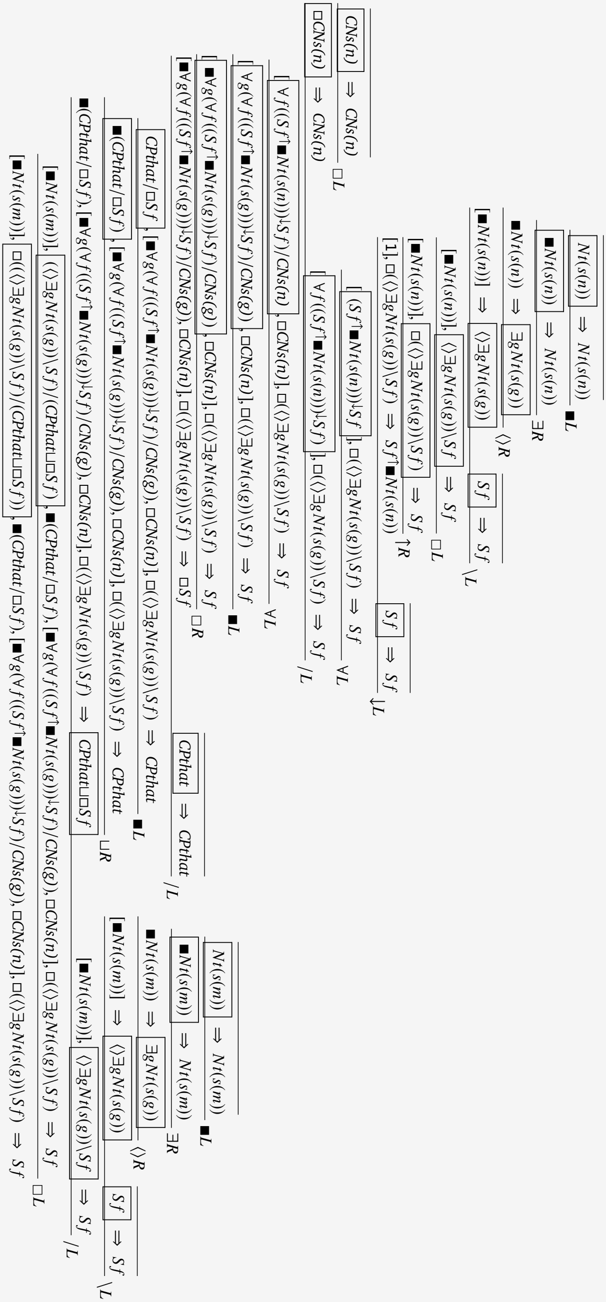

Figure 4 Second derivation of (dwp((7-43, 45)))

$\Box(\langle\rangle\exists gNt(s(g))\backslash Sf) : {}^\wedge\lambda H({}^\vee walk\ H)], \Box(\langle\rangle\exists gNt(s(g))\backslash Sf) :$
${}^\wedge\lambda I({}^\vee talk\ I) \ \Rightarrow\ Sf$

(Derivation omitted)

$\forall C[[({}^\vee fish\ C) \wedge ({}^\vee walk\ C)] \rightarrow ({}^\vee talk\ C)]$

(dwp((7-60, 62))) [**john**]+**seeks**+**a**+**unicorn** : Sf

$[\blacksquare Nt(s(m)) : j], \Box((\langle\rangle\exists gNt(s(g))\backslash Sf)/$
$\quad \Box\forall a\forall f(((Na\backslash Sf)/\exists bNb)\backslash(Na\backslash Sf))) :$
${}^\wedge\lambda A\lambda B(({}^\vee try\ {}^\wedge(({}^\vee A\ {}^\vee find)\ B))\ B), \blacksquare\forall g(\forall f((Sf{\uparrow}\blacksquare Nt(s(g))){\downarrow}Sf)/CNs(g)) :$
$\lambda C\lambda D\exists E[(C\ E) \wedge (D\ E)], \Box CNs(n) : unicorn \ \Rightarrow\ Sf$

For the derivation, see figure 5.

$\exists C[({}^\vee unicorn\ C) \wedge (({}^\vee try\ {}^\wedge(({}^\vee find\ C)\ j))\ j)]$

For the derivation, see figure 6.

$(({}^\vee try\ {}^\wedge\exists G[({}^\vee unicorn\ G) \wedge (({}^\vee find\ G)\ j)])\ j)$

(dwp((7-73))) [**john**]+**is**+**bill** : Sf

$[\blacksquare Nt(s(m)) : j],$
$\blacksquare((\langle\rangle\exists gNt(s(g))\backslash Sf)/(\exists aNa\oplus(\exists g((CNg/CNg)\sqcup(CNg\backslash CNg)){-}I))) :$
$\lambda A\lambda B(A \rightarrow C.[B = C]; D.((D\ \lambda E[E = B])\ B)), \blacksquare Nt(s(m)) : b \ \Rightarrow\ Sf$

For the derivation, see figure 7.

$[j = b]$

(dwp((7-76))) [**john**]+**is**+**a**+**man** : Sf

$[\blacksquare Nt(s(m)) : j],$
$\blacksquare((\langle\rangle\exists gNt(s(g))\backslash Sf)/(\exists aNa\oplus(\exists g((CNg/CNg)\sqcup(CNg\backslash CNg)){-}I))) :$
$\lambda A\lambda B(A \rightarrow C.[B = C]; D.((D\ \lambda E[E = B])\ B)),$
$\blacksquare\forall g(\forall f((Sf{\uparrow}\blacksquare Nt(s(g))){\downarrow}Sf)/CNs(g)) : \lambda F\lambda G\exists H[(F\ H) \wedge (G\ H)],$
$\Box CNs(m) : man \ \Rightarrow\ Sf$

For the derivation, see figure 8.

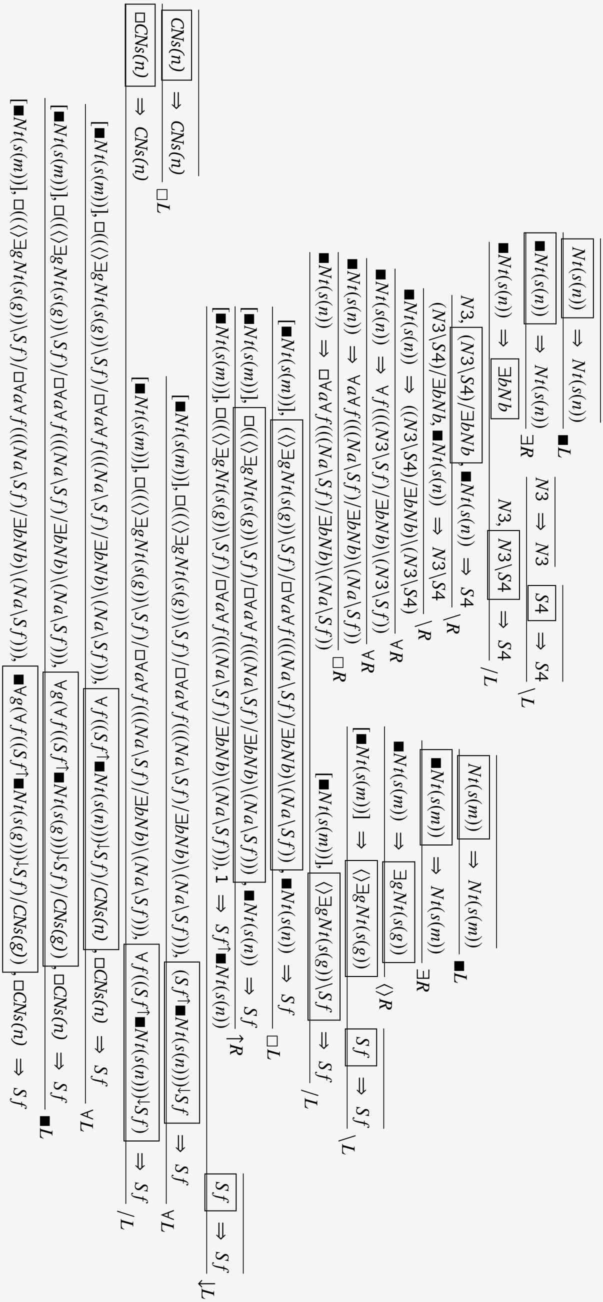

Figure 5 First derivation of (dwp((7-60, 62)))

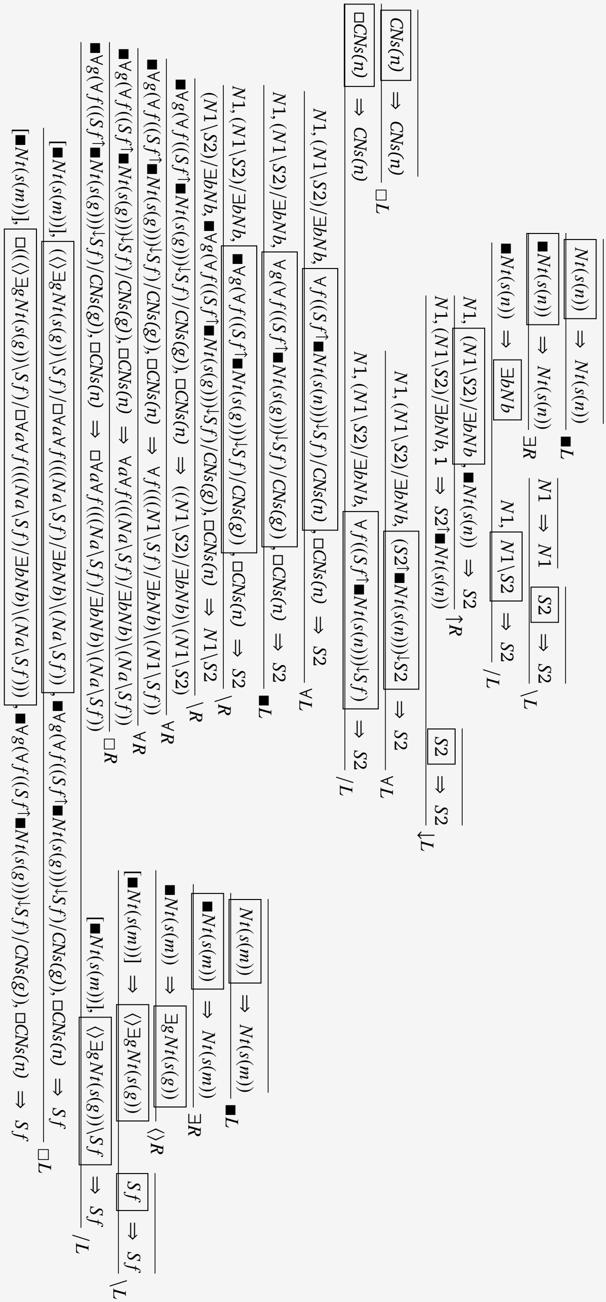

Figure 6 Second derivation of (dwp((7-60, 62)))

$$
\dfrac{
\dfrac{
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\dfrac{
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\dfrac{}{\boxed{Nt(s(m))} \Rightarrow Nt(s(m))}
}{\boxed{\blacksquare Nt(s(m))} \Rightarrow Nt(s(m))}\,\blacksquare L
}{\blacksquare Nt(s(m)) \Rightarrow \boxed{\exists aNa}}\,\exists R
}{\blacksquare Nt(s(m)) \Rightarrow \boxed{\exists aNa{\oplus}(\exists g((CNg/CNg){\sqcup}(CNg\backslash CNg)){-}I)}}\,\oplus R
\quad
\dfrac{
\dfrac{
\dfrac{
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\dfrac{}{\boxed{Nt(s(m))} \Rightarrow Nt(s(m))}
}{\boxed{\blacksquare Nt(s(m))} \Rightarrow Nt(s(m))}\,\blacksquare L
}{\blacksquare Nt(s(m)) \Rightarrow \boxed{\exists gNt(s(g))}}\,\exists R
}{[\blacksquare Nt(s(m))] \Rightarrow \boxed{\langle\rangle\exists gNt(s(g))}}\,\langle\rangle R
\quad
\dfrac{}{\boxed{Sf} \Rightarrow Sf}
}{[\blacksquare Nt(s(m))], \boxed{\langle\rangle\exists gNt(s(g))\backslash Sf} \Rightarrow Sf}\,\backslash L
}{[\blacksquare Nt(s(m))], \boxed{(\langle\rangle\exists gNt(s(g))\backslash Sf)/(\exists aNa{\oplus}(\exists g((CNg/CNg){\sqcup}(CNg\backslash CNg)){-}I))}, \blacksquare Nt(s(m)) \Rightarrow Sf}\,/L
}{[\blacksquare Nt(s(m))], \boxed{\blacksquare((\langle\rangle\exists gNt(s(g))\backslash Sf)/(\exists aNa{\oplus}(\exists g((CNg/CNg){\sqcup}(CNg\backslash CNg)){-}I)))}, \blacksquare Nt(s(m)) \Rightarrow Sf}\,\blacksquare L
$$

Figure 7 Derivation of (dwp((7-73)))

$\exists C[(\check{}man\ C) \wedge [j = C]]$

(dwp((7-83))) **necessarily+[john]+walks** : Sf

$\blacksquare(SA/\Box SA) : Nec, [\blacksquare Nt(s(m)) : j], \Box(\langle\rangle\exists gNt(s(g))\backslash Sf) :$
$\hat{}\lambda B(\check{}walk\ B) \ \Rightarrow\ Sf$

(Derivation omitted)

$(Nec\ \hat{}((\check{}walk\ j))$

(dwp((7-86))) **[john]+walks+slowly** : Sf

$[\blacksquare Nt(s(m)) : j], \Box(\langle\rangle\exists gNt(s(g))\backslash Sf) : \hat{}\lambda A(\check{}walk\ A),$
$\Box\forall a\forall f(\Box(\langle\rangle Na\backslash Sf)\backslash(\langle\rangle\Box Na\backslash Sf)) : \hat{}\lambda B\lambda C(\check{}slowly\ \hat{}(\check{}B\ \check{}C)) \ \Rightarrow\ Sf$

(Derivation omitted)

$(\check{}slowly\ \hat{}(\check{}walk\ j))$

(dwp((7-91))) **[john]+tries+to+walk** : Sf

$[\blacksquare Nt(s(m)) : j], \Box((\langle\rangle\exists gNt(s(g))\backslash Sf)/\Box(\langle\rangle\exists gNt(s(g))\backslash Si)) :$
$\hat{}\lambda A\lambda B((\check{}try\ \hat{}(\check{}A\ B))\ B), \blacksquare((PPto/\exists aNa)\sqcap\forall n((\langle\rangle Nn\backslash Si)/(\langle\rangle Nn\backslash Sb))) :$
$\lambda CC, \Box(\langle\rangle\exists aNa\backslash Sb) : \hat{}\lambda D(\check{}walk\ D) \ \Rightarrow\ Sf$

(Derivation omitted)

$((\check{}try\ \hat{}(\check{}walk\ j))\ j)$

(dwp((7-94))) **[john]+tries+to+[[catch+a+fish+and+eat+it]]** : Sf

$$
\begin{prooftree}
\AxiomC{}
\UnaryInfC{$\boxed{CNs(m)} \Rightarrow CNs(m)$}
\RightLabel{$\Box L$}
\UnaryInfC{$\boxed{\Box CNs(m)} \Rightarrow CNs(m)$}
\AxiomC{}
\UnaryInfC{$\boxed{Nt(s(m))} \Rightarrow Nt(s(m))$}
\RightLabel{$\blacksquare L$}
\UnaryInfC{$\boxed{\blacksquare Nt(s(m))} \Rightarrow Nt(s(m))$}
\RightLabel{$\exists R$}
\UnaryInfC{$\blacksquare Nt(s(m)) \Rightarrow \boxed{\exists aNa}$}
\RightLabel{$\oplus R$}
\UnaryInfC{$\blacksquare Nt(s(m)) \Rightarrow \boxed{\exists aNa\oplus(\exists g((CNg/CNg)\sqcup(CNg\backslash CNg))-I)}$}
\AxiomC{}
\UnaryInfC{$\boxed{Nt(s(m))} \Rightarrow Nt(s(m))$}
\RightLabel{$\blacksquare L$}
\UnaryInfC{$\boxed{\blacksquare Nt(s(m))} \Rightarrow Nt(s(m))$}
\RightLabel{$\exists R$}
\UnaryInfC{$\blacksquare Nt(s(m)) \Rightarrow \boxed{\exists gNt(s(g))}$}
\RightLabel{$\langle\rangle R$}
\UnaryInfC{$[\blacksquare Nt(s(m))] \Rightarrow \boxed{\langle\rangle\exists gNt(s(g))}$}
\AxiomC{}
\UnaryInfC{$\boxed{Sf} \Rightarrow Sf$}
\RightLabel{$\backslash L$}
\BinaryInfC{$[\blacksquare Nt(s(m))], \boxed{\langle\rangle\exists gNt(s(g))\backslash Sf} \Rightarrow Sf$}
\RightLabel{$/L$}
\BinaryInfC{$[\blacksquare Nt(s(m))], \boxed{(\langle\rangle\exists gNt(s(g))\backslash Sf)/(\exists aNa\oplus(\exists g((CNg/CNg)\sqcup(CNg\backslash CNg))-I))}, \blacksquare Nt(s(m)) \Rightarrow Sf$}
\RightLabel{$\blacksquare L$}
\UnaryInfC{$[\blacksquare Nt(s(m))], \boxed{\blacksquare((\langle\rangle\exists gNt(s(g))\backslash Sf)/(\exists aNa\oplus(\exists g((CNg/CNg)\sqcup(CNg\backslash CNg))-I)))}, \blacksquare Nt(s(m)) \Rightarrow Sf$}
\RightLabel{$\uparrow R$}
\UnaryInfC{$[\blacksquare Nt(s(m))], \blacksquare(((\langle\rangle\exists gNt(s(g))\backslash Sf)/(\exists aNa\oplus(\exists g((CNg/CNg)\sqcup(CNg\backslash CNg))-I))), 1 \Rightarrow Sf{\uparrow}\blacksquare Nt(s(m))$}
\AxiomC{}
\UnaryInfC{$\boxed{Sf} \Rightarrow Sf$}
\RightLabel{$\downarrow L$}
\BinaryInfC{$[\blacksquare Nt(s(m))], \blacksquare(((\langle\rangle\exists gNt(s(g))\backslash Sf)/(\exists aNa\oplus(\exists g((CNg/CNg)\sqcup(CNg\backslash CNg))-I))), \boxed{(Sf{\uparrow}\blacksquare Nt(s(m)))^{\downarrow}Sf} \Rightarrow Sf$}
\RightLabel{$\forall L$}
\UnaryInfC{$[\blacksquare Nt(s(m))], \blacksquare(((\langle\rangle\exists gNt(s(g))\backslash Sf)/(\exists aNa\oplus(\exists g((CNg/CNg)\sqcup(CNg\backslash CNg))-I))), \boxed{\forall f((Sf{\uparrow}\blacksquare Nt(s(m)))^{\downarrow}Sf)} \Rightarrow Sf$}
\RightLabel{$/L$}
\BinaryInfC{$[\blacksquare Nt(s(m))], \blacksquare(((\langle\rangle\exists gNt(s(g))\backslash Sf)/(\exists aNa\oplus(\exists g((CNg/CNg)\sqcup(CNg\backslash CNg))-I))), \boxed{\forall f((Sf{\uparrow}\blacksquare Nt(s(m)))^{\downarrow}Sf)/CNs(m)}, \Box CNs(m) \Rightarrow Sf$}
\RightLabel{$\forall L$}
\UnaryInfC{$[\blacksquare Nt(s(m))], \blacksquare(((\langle\rangle\exists gNt(s(g))\backslash Sf)/(\exists aNa\oplus(\exists g((CNg/CNg)\sqcup(CNg\backslash CNg))-I))), \boxed{\forall g(\forall f((Sf{\uparrow}\blacksquare Nt(s(g)))^{\downarrow}Sf)/CNs(g))}, \Box CNs(m) \Rightarrow Sf$}
\RightLabel{$\blacksquare L$}
\UnaryInfC{$[\blacksquare Nt(s(m))], \blacksquare(((\langle\rangle\exists gNt(s(g))\backslash Sf)/(\exists aNa\oplus(\exists g((CNg/CNg)\sqcup(CNg\backslash CNg))-I))), \boxed{\blacksquare\forall g(\forall f((Sf{\uparrow}\blacksquare Nt(s(g)))^{\downarrow}Sf)/CNs(g))}, \Box CNs(m) \Rightarrow Sf$}
\end{prooftree}
$$

Figure 8 Derivation of (dwp((7-76)))

$[\blacksquare Nt(s(m)) : j], \square((\langle\rangle\exists gNt(s(g))\backslash Sf)/\square(\langle\rangle\exists gNt(s(g))\backslash Si)) :$
$\hat{}\lambda A\lambda B((\check{}\mathit{try}\ \hat{}(\check{}A\ B))\ B), \blacksquare((PPto/\exists aNa)\sqcap\forall n((\langle\rangle Nn\backslash Si)/(\langle\rangle Nn\backslash Sb))) :$
$\lambda CC, [[\square((\langle\rangle\exists aNa\backslash Sb)/\exists aNa) : \hat{}\lambda D\lambda E((\check{}\mathit{catch}\ D)\ E),$
$\blacksquare\forall g(\forall f((Sf{\uparrow}\blacksquare Nt(s(g))){\downarrow}Sf)/CNs(g)) : \lambda F\lambda G\exists H[(F\ H) \wedge (G\ H)],$
$\square CNs(n) : \mathit{fish}, \blacksquare\forall f((\blacksquare ?Sf\backslash[]^{-1}[]^{-1}Sf)/\blacksquare Sf) : (\Phi^{n+}\ o\ \mathit{and}),$
$\square((\langle\rangle\exists aNa\backslash Sb)/\exists aNa) : \hat{}\lambda I\lambda J((\check{}\mathit{eat}\ I)\ J),$
$\blacksquare\forall f\forall a((((\langle\rangle Na\backslash Sf){\uparrow}\blacksquare Nt(s(n))){\downarrow}(\blacksquare(\langle\rangle Na\backslash Sf)|\blacksquare Nt(s(n)))) : \lambda KK]] \ \Rightarrow\ Sf$

$[\blacksquare Nt(s(m)) : j], \square((\langle\rangle\exists gNt(s(g))\backslash Sf)/\square(\langle\rangle\exists gNt(s(g))\backslash Si)) :$
$\hat{}\lambda A\lambda B((\check{}\mathit{try}\ \hat{}(\check{}A\ B))\ B), \blacksquare((PPto/\exists aNa)\sqcap\forall n((\langle\rangle Nn\backslash Si)/(\langle\rangle Nn\backslash Sb))) :$
$\lambda CC, [[\square((\langle\rangle\exists aNa\backslash Sb)/\exists aNa) : \hat{}\lambda D\lambda E((\check{}\mathit{catch}\ D)\ E),$
$\blacksquare\forall g(\forall f((Sf{\uparrow}\blacksquare Nt(s(g))){\downarrow}Sf)/CNs(g)) : \lambda F\lambda G\exists H[(F\ H) \wedge (G\ H)],$
$\square CNs(n) : \mathit{fish}, \blacksquare\forall f((\blacksquare ?Sf\backslash[]^{-1}[]^{-1}Sf)/\blacksquare Sf) : (\Phi^{n+}\ o\ \mathit{and}),$
$\square((\langle\rangle\exists aNa\backslash Sb)/\exists aNa) : \hat{}\lambda I\lambda J((\check{}\mathit{eat}\ I)\ J),$
$\blacksquare[]^{-1}\forall f((\blacksquare Sf|\blacksquare Nt(s(n)))/(\langle\rangle Nt(s(n))\backslash Sf)) : \lambda KK]] \ \Rightarrow\ Sf$

$[\blacksquare Nt(s(m)) : j], \square((\langle\rangle\exists gNt(s(g))\backslash Sf)/\square(\langle\rangle\exists gNt(s(g))\backslash Si)) :$
$\hat{}\lambda A\lambda B((\check{}\mathit{try}\ \hat{}(\check{}A\ B))\ B), \blacksquare((PPto/\exists aNa)\sqcap\forall n((\langle\rangle Nn\backslash Si)/(\langle\rangle Nn\backslash Sb))) :$
$\lambda CC, [[\square((\langle\rangle\exists aNa\backslash Sb)/\exists aNa) : \hat{}\lambda D\lambda E((\check{}\mathit{catch}\ D)\ E),$
$\blacksquare\forall g(\forall f((Sf{\uparrow}\blacksquare Nt(s(g))){\downarrow}Sf)/CNs(g)) : \lambda F\lambda G\exists H[(F\ H) \wedge (G\ H)],$
$\square CNs(n) : \mathit{fish}, \blacksquare\forall a\forall f((\blacksquare ?(\langle\rangle Na\backslash Sf)\backslash[]^{-1}[]^{-1}(\langle\rangle Na\backslash Sf))/\blacksquare(\langle\rangle Na\backslash Sf)) :$
$(\Phi^{n+}\ (s\ o)\ \mathit{and}), \square((\langle\rangle\exists aNa\backslash Sb)/\exists aNa) : \hat{}\lambda I\lambda J((\check{}\mathit{eat}\ I)\ J),$
$\blacksquare\forall f\forall a((((\langle\rangle Na\backslash Sf){\uparrow}\blacksquare Nt(s(n))){\downarrow}(\blacksquare(\langle\rangle Na\backslash Sf)|\blacksquare Nt(s(n)))) : \lambda KK]] \ \Rightarrow\ Sf$

(Derivation omitted)

$\exists C[(\check{}\mathit{fish}\ C) \wedge ((\check{}\mathit{try}\ \hat{}[((\check{}\mathit{catch}\ C)\ j) \wedge ((\check{}\mathit{eat}\ C)\ j)])\ j)]$

(Derivation omitted)

$((\check{}\mathit{try}\ \hat{}\exists F[(\check{}\mathit{fish}\ F) \wedge [((\check{}\mathit{catch}\ F)\ j) \wedge ((\check{}\mathit{eat}\ F)\ j)]])\ j)$

$((\check{}\mathit{try}\ \hat{}\exists H[(\check{}\mathit{fish}\ H) \wedge [((\check{}\mathit{catch}\ H)\ j) \wedge ((\check{}\mathit{eat}\ H)\ j)]])\ j)$

$[\blacksquare Nt(s(m)) : j], \square((\langle\rangle\exists gNt(s(g))\backslash Sf)/\square(\langle\rangle\exists gNt(s(g))\backslash Si)) :$
$\hat{}\lambda A\lambda B((\check{}\mathit{try}\ \hat{}(\check{}A\ B))\ B), \blacksquare((PPto/\exists aNa)\sqcap\forall n((\langle\rangle Nn\backslash Si)/(\langle\rangle Nn\backslash Sb))) :$
$\lambda CC, [[\square((\langle\rangle\exists aNa\backslash Sb)/\exists aNa) : \hat{}\lambda D\lambda E((\check{}\mathit{catch}\ D)\ E),$
$\blacksquare\forall g(\forall f((Sf{\uparrow}\blacksquare Nt(s(g))){\downarrow}Sf)/CNs(g)) : \lambda F\lambda G\exists H[(F\ H) \wedge (G\ H)],$
$\square CNs(n) : \mathit{fish}, \blacksquare\forall a\forall f((\blacksquare ?(\langle\rangle Na\backslash Sf)\backslash[]^{-1}[]^{-1}(\langle\rangle Na\backslash Sf))/\blacksquare(\langle\rangle Na\backslash Sf)) :$

\begin{prooftree}
\AxiomC{$\boxed{CNs(n)} \Rightarrow CNs(n)$}
\RightLabel{$\Box L$}
\UnaryInfC{$\boxed{\Box CNs(n)} \Rightarrow CNs(n)$}
\AxiomC{$\boxed{Nt(s(n))} \Rightarrow Nt(s(n))$}
\RightLabel{$\blacksquare L$}
\UnaryInfC{$\boxed{\blacksquare Nt(s(n))} \Rightarrow Nt(s(n))$}
\RightLabel{$\exists R$}
\UnaryInfC{$\blacksquare Nt(s(n)) \Rightarrow \boxed{\exists aNa}$}
\AxiomC{$\boxed{Nt(s(m))} \Rightarrow Nt(s(m))$}
\RightLabel{$\blacksquare L$}
\UnaryInfC{$\boxed{\blacksquare Nt(s(m))} \Rightarrow Nt(s(m))$}
\RightLabel{$\exists R$}
\UnaryInfC{$\blacksquare Nt(s(m)) \Rightarrow \boxed{\exists gNt(s(g))}$}
\RightLabel{$\langle\rangle R$}
\UnaryInfC{$[\blacksquare Nt(s(m))] \Rightarrow \boxed{\langle\rangle\exists gNt(s(g))}$}
\AxiomC{$\boxed{Sf} \Rightarrow Sf$}
\RightLabel{$\backslash L$}
\BinaryInfC{$[\blacksquare Nt(s(m))], \boxed{\langle\rangle\exists gNt(s(g))\backslash Sf} \Rightarrow Sf$}
\RightLabel{$/L$}
\BinaryInfC{$[\blacksquare Nt(s(m))], \boxed{(\langle\rangle\exists gNt(s(g))\backslash Sf)/\exists aNa}, \blacksquare Nt(s(n)) \Rightarrow Sf$}
\RightLabel{$\Box L$}
\UnaryInfC{$[\blacksquare Nt(s(m))], \boxed{\Box((\langle\rangle\exists gNt(s(g))\backslash Sf)/\exists aNa)}, \blacksquare Nt(s(n)) \Rightarrow Sf$}
\RightLabel{$\uparrow R$}
\UnaryInfC{$[\blacksquare Nt(s(m))], \Box((\langle\rangle\exists gNt(s(g))\backslash Sf)/\exists aNa), 1 \Rightarrow Sf{\uparrow}\blacksquare Nt(s(n))$}
\AxiomC{$\boxed{Sf} \Rightarrow Sf$}
\RightLabel{$\downarrow L$}
\BinaryInfC{$[\blacksquare Nt(s(m))], \Box((\langle\rangle\exists gNt(s(g))\backslash Sf)/\exists aNa), \boxed{(Sf{\uparrow}\blacksquare Nt(s(n))){\downarrow}Sf} \Rightarrow Sf$}
\RightLabel{$\forall L$}
\UnaryInfC{$[\blacksquare Nt(s(m))], \Box((\langle\rangle\exists gNt(s(g))\backslash Sf)/\exists aNa), \boxed{\forall f((Sf{\uparrow}\blacksquare Nt(s(n))){\downarrow}Sf)} \Rightarrow Sf$}
\RightLabel{$/L$}
\BinaryInfC{$[\blacksquare Nt(s(m))], \Box((\langle\rangle\exists gNt(s(g))\backslash Sf)/\exists aNa), \boxed{\forall f((Sf{\uparrow}\blacksquare Nt(s(n))){\downarrow}Sf)/CNs(n)}, \Box CNs(n) \Rightarrow Sf$}
\RightLabel{$\forall L$}
\UnaryInfC{$[\blacksquare Nt(s(m))], \Box((\langle\rangle\exists gNt(s(g))\backslash Sf)/\exists aNa), \boxed{\forall g(\forall f((Sf{\uparrow}\blacksquare Nt(s(g))){\downarrow}Sf)/CNs(g))}, \Box CNs(n) \Rightarrow Sf$}
\RightLabel{$\blacksquare L$}
\UnaryInfC{$[\blacksquare Nt(s(m))], \Box((\langle\rangle\exists gNt(s(g))\backslash Sf)/\exists aNa), \boxed{\blacksquare\forall g(\forall f((Sf{\uparrow}\blacksquare Nt(s(g))){\downarrow}Sf)/CNs(g))}, \Box CNs(n) \Rightarrow Sf$}
\end{prooftree}

Figure 9 Derivation of (dwp((7-98)))

$(\Phi^{n+}\ (s\ 0)\ and), \Box((\langle\rangle\exists aNa\backslash Sb)/\exists aNa) : \hat{}\lambda I\lambda J((\check{}eat\ I)\ J),$
$\blacksquare[]^{-1}\forall f((\blacksquare Sf|\blacksquare Nt(s(n)))/(\langle\rangle Nt(s(n))\backslash Sf)) : \lambda KK]] \Rightarrow Sf$

(dwp((7-98))) [**john**]+**finds**+**a**+**unicorn** : Sf

$[\blacksquare Nt(s(m)) : j], \Box((\langle\rangle\exists gNt(s(g))\backslash Sf)/\exists aNa) : \hat{}\lambda A\lambda B((\check{}find\ A)\ B),$
$\blacksquare\forall g(\forall f((Sf{\uparrow}\blacksquare Nt(s(g))){\downarrow}Sf)/CNs(g)) : \lambda C\lambda D\exists E[(C\ E) \wedge (D\ E)],$
$\Box CNs(n) : unicorn \Rightarrow Sf$

For the derivation, see figure 9.

$\exists C[(\check{}unicorn\ C) \wedge ((\check{}find\ C)\ j)]$

(dwp((7-105))) [**every**+**man**+**such**+**that**+[**he**]+**loves**+**a**+**woman**]
+**loses**+**her** : Sf

$[\blacksquare\forall g(\forall f((Sf{\uparrow}Nt(s(g))){\downarrow}Sf)/CNs(g)) : \lambda A\lambda B\forall C[(A\ C) \rightarrow (B\ C)],$
$\Box CNs(m) : man, \blacksquare\forall n((CNn\backslash CNn)/(Sf|\blacksquare Nt(n))) : \lambda D\lambda E\lambda F[(E\ F) \wedge (D\ F)],$
$[\blacksquare[]^{-1}\forall g((\blacksquare Sg|\blacksquare Nt(s(m)))/(\langle\rangle Nt(s(m))\backslash Sg)) : \lambda GG],$
$\Box((\langle\rangle\exists gNt(s(g))\backslash Sf)/\exists aNa) : \hat{}\lambda H\lambda I((\check{}love\ H)\ I),$
$\blacksquare\forall g(\forall f((Sf{\uparrow}\blacksquare Nt(s(g))){\downarrow}Sf)/CNs(g)) : \lambda J\lambda K\exists L[(J\ L) \wedge (K\ L)],$
$\Box CNs(f) : woman],$
$\Box((\langle\rangle\exists gNt(s(g))\backslash Sf)/\exists aNa) : \hat{}\lambda M\lambda N((\check{}lose\ M)\ N),$
$\blacksquare\forall g\forall a(((\langle\rangle Na\backslash Sg){\uparrow}\blacksquare Nt(s(f))){\downarrow}(\blacksquare(\langle\rangle Na\backslash Sg)|\blacksquare Nt(s(f)))) : \lambda OO \Rightarrow Sf$

(Derivation omitted)

$\exists C[({}^{\vee}woman\ C) \wedge \forall G[[({}^{\vee}man\ G) \wedge (({}^{\vee}love\ C)\ G)] \rightarrow (({}^{\vee}lose\ C)\ G)]]$

(dwp((7-110))) [**john**]+**walks**+**in**+**a**+**park** : Sf

$[\blacksquare Nt(s(m)) : j], \square(\langle\rangle \exists g Nt(s(g)) \backslash Sf) : {}^{\wedge}\lambda A({}^{\vee}walk\ A),$
$\square(\forall a \forall f((\langle\rangle Na \backslash Sf) \backslash (\langle\rangle Na \backslash Sf))/\exists a Na) : {}^{\wedge}\lambda B \lambda C \lambda D(({}^{\vee}in\ B)\ (C\ D)),$
$\blacksquare \forall g(\forall f((Sf \uparrow \blacksquare Nt(s(g))) \downarrow Sf)/CNs(g)) : \lambda E \lambda F \exists G[(E\ G) \wedge (F\ G)],$
$\square CNs(n) : park \ \Rightarrow \ Sf$

(Derivation omitted)

$\exists C[({}^{\vee}park\ C) \wedge (({}^{\vee}in\ C)\ ({}^{\vee}walk\ j))]$

(dwp((7-116, 118))) [**every**+**man**]+**doesnt**+**walk** : Sf

$[\blacksquare \forall g(\forall f((Sf \uparrow Nt(s(g))) \downarrow Sf)/CNs(g)) : \lambda A \lambda B \forall C[(A\ C) \rightarrow (B\ C)],$
$\square CNs(m) : man], \blacksquare \forall g \forall a((Sg \uparrow ((\langle\rangle Na \backslash Sf)/(\langle\rangle Na \backslash Sb))) \downarrow Sg) :$
$\lambda D \neg(D\ \lambda E \lambda F(E\ F)), \square(\langle\rangle \exists a Na \backslash Sb) : {}^{\wedge}\lambda G({}^{\vee}walk\ G) \ \Rightarrow \ Sf$

(Derivation omitted)

$\forall C[({}^{\vee}man\ C) \rightarrow \neg({}^{\vee}walk\ C)]$

(Derivation omitted)

$\neg \forall G[({}^{\vee}man\ G) \rightarrow ({}^{\vee}walk\ G)]$

Appendix: Rules

The syntactic types of displacement logic are sorted $\mathscr{F}_0, \mathscr{F}_1, \mathscr{F}_2, \ldots$ according to the number of points of discontinuity $0, 1, 2, \ldots$ their expressions contain. Each type predicate letter has a sort and an arity which are naturals, and a corresponding semantic type. Assuming ordinary terms to be already given, where P is a type predicate letter of sort i and arity n and $t_1, \ldots, t_n$ are terms, $Pt_1 \ldots t_n$ is an (atomic) type of sort i of the corresponding semantic type. Compound types are formed by connectives as indicated in table 2,[2] and the structure preserving semantic type map T

[2] We list only connectives drawn from the first two rows of table 1, omitting some which are not central here.

1.	$\mathcal{F}_i$	::=	$\mathcal{F}_{i+j}/\mathcal{F}_j$	$T(C/B)$	=	$T(B){\to}T(C)$	over
2.	$\mathcal{F}_j$	::=	$\mathcal{F}_i\backslash\mathcal{F}_{i+j}$	$T(A\backslash C)$	=	$T(A){\to}T(C)$	under
3.	$\mathcal{F}_{i+j}$	::=	$\mathcal{F}_i{\bullet}\mathcal{F}_j$	$T(A{\bullet}B)$	=	$T(A)\&T(B)$	continuous product
4.	$\mathcal{F}_0$	::=	I	$T(I)$	=	$\top$	continuous unit
5.	$\mathcal{F}_{i+1}$	::=	$\mathcal{F}_{i+j}{\uparrow_k}\mathcal{F}_j, 1 \leq k \leq i{+}j$	$T(C{\uparrow_k}B)$	=	$T(B){\to}T(C)$	extract
6.	$\mathcal{F}_j$	::=	$\mathcal{F}_{i+1}{\downarrow_k}\mathcal{F}_{i+j}, 1 \leq k \leq i{+}1$	$T(A{\downarrow_k}C)$	=	$T(A){\to}T(C)$	infix
7.	$\mathcal{F}_{i+j}$	::=	$\mathcal{F}_{i+1}{\odot_k}\mathcal{F}_j, 1 \leq k \leq i{+}1$	$T(A{\odot_k}B)$	=	$T(A)\&T(B)$	discontinuous product
8.	$\mathcal{F}_1$	::=	J	$T(J)$	=	$\top$	discontinuous unit
9.	$\mathcal{F}_i$	::=	$\mathcal{F}_i\&\mathcal{F}_i$	$T(A\&B)$	=	$T(A)\&T(B)$	additive conjunction
10.	$\mathcal{F}_i$	::=	$\mathcal{F}_i\oplus\mathcal{F}_i$	$T(A\oplus B)$	=	$T(A){+}T(B)$	additive disjunction
11.	$\mathcal{F}_i$	::=	$\bigwedge V\mathcal{F}_i$	$T(\bigwedge vA)$	=	$F{\to}T(A)$	1st order univ. qu.
12.	$\mathcal{F}_i$	::=	$\bigvee V\mathcal{F}_i$	$T(\bigvee vA)$	=	$F\&T(A)$	1st order exist. qu.
13.	$\mathcal{F}_i$	::=	$\Box\mathcal{F}_i$	$T(\Box A)$	=	$\mathbf{L}T(A)$	universal modality
14.	$\mathcal{F}_i$	::=	$\Diamond\mathcal{F}_i$	$T(\Diamond A)$	=	$\mathbf{M}T(A)$	existential modality
15.	$\mathcal{F}_i$	::=	$[\,]^{-1}\mathcal{F}_i$	$T([\,]^{-1}A)$	=	$T(A)$	univ. bracket modality
16.	$\mathcal{F}_i$	::=	$\langle\rangle\mathcal{F}_i$	$T(\langle\rangle A)$	=	$T(A)$	exist. bracket modality
17.	$\mathcal{F}_0$	::=	$!\mathcal{F}_0$	$T(!A)$	=	$T(A)$	universal exponential
18.	$\mathcal{F}_0$	::=	$?\mathcal{F}_0$	$T(?A)$	=	$T(A)^+$	existential exponential
19.	$\mathcal{F}_{i+j}$	::=	$\mathcal{F}_{i+j}\vert\mathcal{F}_j$	$T(B\vert A)$	=	$T(A){\to}T(B)$	contr. for anaph.
35.	$\mathcal{F}_i$	::=	$\forall V\mathcal{F}_i$	$T(\forall vA)$	=	$T(A)$	sem. inactive 1st order univ. qu.
36.	$\mathcal{F}_i$	::=	$\exists V\mathcal{F}_i$	$T(\exists vA)$	=	$T(A)$	sem. inactive 1st order exist. qu.
37.	$\mathcal{F}_i$	::=	$\blacksquare\mathcal{F}_i$	$T(\blacksquare A)$	=	$T(A)$	sem. inactive universal modality
38.	$\mathcal{F}_i$	::=	$\blacklozenge\mathcal{F}_i$	$T(\blacklozenge A)$	=	$T(A)$	sem. inactive existential modality

Table 2 Syntactic types

associates these with semantic types.

In Gentzen sequent configurations (Γ, Δ) for displacement calculus a discontinuous type is a mother, rather than a leaf, and dominates its discontinuous components marked off by curly brackets and colons.

In Gentzen sequent antecedents for displacement logic with bracket modalities (structural inhibition) and exponentials (structural facilitation) there is also a bracket constructor for the former and 'stoups' for the latter.

Stoups (cf. the linear logic of Girard 2011 (ζ) are stores read as multisets for re-usable (nonlinear) resources which appear at the left of a configuration marked off by a semicolon (when the stoup is empty the semicolon may be omitted, as in the derivations of the previous section). The stoup of linear logic is for resources which can be contracted (copied) or weakened (deleted). By contrast, our stoup is for a linguistically motivated variant of contraction, and does not allow weakening. Furthermore, whereas linear logic is commutative, our logic is in general noncommutative and the stoup is used for resources which are also commutative.

A configuration together with a stoup is a *zone* (Ξ). The bracket constructor applies not to a configuration alone but to a configuration with a stoup, i.e a zone: reusable resources are specific to their domain.

Stoups $\mathcal{S}$ and configurations $\mathcal{O}$ are defined by ($\emptyset$ is the empty stoup; Λ is the empty configuration; the *separator* 1 marks points of discontinuity.:[3]

$$\text{(1)}\quad \begin{array}{lcl} \mathcal{S} & ::= & \emptyset \mid \mathcal{F}_0, \mathcal{S} \\ \mathcal{O} & ::= & \Lambda \mid \mathcal{T}, \mathcal{O} \\ \mathcal{T} & ::= & 1 \mid \mathcal{F}_0 \mid \mathcal{F}_{i>0}\{\underbrace{\mathcal{O} : \ldots : \mathcal{O}}_{i\ \mathcal{O}'\mathrm{s}}\} \mid [\mathcal{S}; \mathcal{O}] \end{array}$$

For a type A, its sort $s(A)$ is the i such that $A \in \mathcal{F}_i$. For a configuration Γ, its sort $s(\Gamma)$ is $|\Gamma|_1$, that is, the number of points of discontinuity 1 which it contains. Sequents are of the form:

$$\text{(2)}\quad \mathcal{S}; \mathcal{O} \Rightarrow \mathcal{F} \text{ such that } s(\mathcal{O}) = s(\mathcal{F})$$

The figure $\overrightarrow{A}$ of a type A is defined by:

$$\text{(3)}\quad \overrightarrow{A} = \begin{cases} A & \text{if } s(A) = 0 \\ A\{\underbrace{1 : \ldots : 1}_{s(A)\ 1'\mathrm{s}}\} & \text{if } s(A) > 0 \end{cases}$$

Where Γ is a configuration of sort i and $\Delta_1, \ldots, \Delta_i$ are configurations, the *fold* $\Gamma \otimes \langle \Delta_1 : \ldots : \Delta_i \rangle$ is the result of replacing the successive 1's in Γ by $\Delta_1, \ldots, \Delta_i$ respectively. Where Γ is of sort i, the hyperoccurrence notation $\Delta\langle\Gamma\rangle$ abbreviates $\Delta_0(\Gamma \otimes \langle \Delta_1 : \ldots : \Delta_i \rangle)$, that is, a context configuration Δ (which is externally Δ_0 and internally $\Delta_1, \ldots, \Delta_i$) with a potentially discontinuous distinguished subconfiguration Γ. Where Δ is a configuration of sort $i > 0$ and Γ is a configuration, the kth *metalinguistic intercalation* $\Delta \,|_k\, \Gamma$, $1 \leq k \leq i$, is given by:

$$\text{(4)}\quad \Delta \,|_k\, \Gamma =_{df} \Delta \otimes \langle \underbrace{1 : \ldots : 1}_{k-1\ 1\text{'s}} : \Gamma : \underbrace{1 : \ldots : 1}_{i-k\ 1\text{'s}} \rangle$$

that is, $\Delta \,|_k\, \Gamma$ is the configuration resulting from replacing by Γ the kth separator in Δ.

[3]Note that only types of sort 0 can go into the stoup; reusable types of other sorts would not preserve the sequent antecedent-succedent sort equality under contraction.

1. $$\frac{\zeta_1; \Gamma \Rightarrow B\colon \psi \qquad \zeta_2; \Delta\langle \overrightarrow{C}\colon z\rangle \Rightarrow D\colon \omega}{\zeta_1 \uplus \zeta_2; \Delta\langle \overrightarrow{C/B}\colon x, \Gamma\rangle \Rightarrow D\colon \omega\{(x\ \psi)/z\}}/L \qquad \frac{\zeta; \Gamma, \overrightarrow{B}\colon y \Rightarrow C\colon \chi}{\zeta; \Gamma \Rightarrow C/B\colon \lambda y\chi}/R$$

2. $$\frac{\zeta_1; \Gamma \Rightarrow A\colon \phi \qquad \zeta_2; \Delta\langle \overrightarrow{C}\colon z\rangle \Rightarrow D\colon \omega}{\zeta_1 \uplus \zeta_2; \Delta\langle \Gamma, \overrightarrow{A\backslash C}\colon y\rangle \Rightarrow D\colon \omega\{(y\ \phi)/z\}}\backslash L \qquad \frac{\zeta; \overrightarrow{A}\colon x, \Gamma \Rightarrow C\colon \chi}{\zeta; \Gamma \Rightarrow A\backslash C\colon \lambda x\chi}\backslash R$$

3. $$\frac{\zeta; \Delta\langle \overrightarrow{A}\colon x, \overrightarrow{B}\colon y\rangle \Rightarrow D\colon \omega}{\zeta; \Delta\langle \overrightarrow{A{\bullet}B}\colon z\rangle \Rightarrow D\colon \omega\{\pi_1 z/x, \pi_2 z/y\}}\bullet L \qquad \frac{\zeta_1; \Gamma_1 \Rightarrow A\colon \phi \qquad \zeta_2; \Gamma_2 \Rightarrow B\colon \psi}{\zeta_1 \uplus \zeta_2; \Gamma_1, \Gamma_2 \Rightarrow A{\bullet}B\colon (\phi, \psi)}\bullet R$$

4. $$\frac{\zeta; \Delta\langle \Lambda\rangle \Rightarrow A\colon \phi}{\zeta; \Delta\langle \overrightarrow{I}\colon x\rangle \Rightarrow A\colon \phi} IL \qquad \frac{}{\emptyset; \Lambda \Rightarrow I\colon 0} IR$$

Figure 10 Continuous multiplicatives

A semantically labelled sequent is a sequent in which the antecedent type occurrences $A_1, \ldots, A_n$ are labelled by distinct variables $x_1, \ldots, x_n$ of types $T(A_1), \ldots, T(A_n)$ respectively, and the succedent type A is labelled by a term of type $T(A)$ with free variables drawn from $x_1, \ldots, x_n$. In this appendix we give the semantically labelled Gentzen sequent rules for some primary connectives, and indicate some linguistic applications.

The continuous multiplicatives of figure 10, the Lambek connectives (Lambek 1958, 1988), defined in relation to appending, are the basic means of categorial categorization and subcategorization. Note that here and throughout the active types in antecedents are figures (vectorial) whereas those in succedents are not; intuitively this is because antecedents are structured but succedents are not. The directional divisions over, /, and under, \, are exemplified by assignments such as **the**: N/CN for **the man**: N, **sings**: $N\backslash S$ for **John sings**: S, and **loves**: $(N\backslash S)/N$ for **John loves Mary**: S. The continuous product $\bullet$ is exemplified by a 'small clause' assignment such as **considers**: $(N\backslash S)/(N{\bullet}(CN/CN))$.

The discontinuous multiplicatives of figure 11, the displacement connectives (Morrill & Valentín 2010, Morrill et al. 2011), are defined in relation to plugging. When the value of the k subindex indicates the first (leftmost) point of discontinuity, it may be omitted. Extraction, $\uparrow$, is exemplified by a discontinuous idiom assignment **gives**+1+**the**+**cold**+**shoulder**: $(N\backslash S)\uparrow N$ for **Mary gives John the cold shoulder**: S, and infixation, $\downarrow$, and extrac-

5. $$\frac{\zeta_1;\Gamma \Rightarrow B\colon\psi \qquad \zeta_2;\Delta\langle\overrightarrow{C}\colon z\rangle \Rightarrow D\colon\omega}{\zeta_1\uplus\zeta_2;\Delta\langle\overrightarrow{C{\uparrow_k}B}\colon x\,|_k\,\Gamma\rangle \Rightarrow D\colon\omega\{(x\ \psi)/z\}}\uparrow_k L \qquad \frac{\zeta;\Gamma\,|_k\,\overrightarrow{B}\colon y \Rightarrow C\colon\chi}{\zeta;\Gamma \Rightarrow C{\uparrow_k}B\colon\lambda y\chi}\uparrow_k R$$

6. $$\frac{\zeta_1;\Gamma \Rightarrow A\colon\phi \qquad \zeta_2;\Delta\langle\overrightarrow{C}\colon z\rangle \Rightarrow D\colon\omega}{\zeta_1\uplus\zeta_2;\Delta\langle\Gamma\,|_k\,\overrightarrow{A{\downarrow_k}C}\colon y\rangle \Rightarrow D\colon\omega\{(y\ \phi)/z\}}\downarrow_k L \qquad \frac{\zeta;\overrightarrow{A}\colon x\,|_k\,\Gamma \Rightarrow C\colon\chi}{\zeta;\Gamma \Rightarrow A{\downarrow_k}C\colon\lambda x\chi}\downarrow_k R$$

7. $$\frac{\zeta;\Delta\langle\overrightarrow{A}\colon x\,|_k\,\overrightarrow{B}\colon y\rangle \Rightarrow D\colon\omega}{\zeta;\Delta\langle\overrightarrow{A{\odot_k}B}\colon z\rangle \Rightarrow D\colon\omega\{\pi_1 z/x,\pi_2 z/y\}}\odot_k L \qquad \frac{\zeta_1;\Gamma_1 \Rightarrow A\colon\phi \qquad \zeta_2;\Gamma_2 \Rightarrow B\colon\psi}{\zeta_1\uplus\zeta_2;\Gamma_1\,|_k\,\Gamma_2 \Rightarrow A{\odot_k}B\colon(\phi,\psi)}\odot_k R$$

8. $$\frac{\zeta;\Delta\langle 1\rangle \Rightarrow A\colon\phi}{\zeta;\Delta\langle\overrightarrow{J}\colon x\rangle \Rightarrow A\colon\phi}JL \qquad \frac{}{\emptyset;1 \Rightarrow J\colon 0}JR$$

Figure 11 Discontinuous multiplicatives

9. $$\frac{\Xi\langle\overrightarrow{A}\colon x\rangle \Rightarrow C\colon\chi}{\Xi\langle\overrightarrow{A\&B}\colon z\rangle \Rightarrow C\colon\chi\{\pi_1 z/x\}}\&L_1 \qquad \frac{\Xi\langle\overrightarrow{B}\colon y\rangle \Rightarrow C\colon\chi}{\Xi\langle\overrightarrow{A\&B}\colon z\rangle \Rightarrow C\colon\chi\{\pi_2 z/y\}}\&L_2 \qquad \frac{\Xi \Rightarrow A\colon\phi \qquad \Xi \Rightarrow B\colon\psi}{\Xi \Rightarrow A\&B\colon(\phi,\psi)}\&R$$

10. $$\frac{\Xi\langle\overrightarrow{A}\colon x\rangle \Rightarrow C\colon\chi_1 \qquad \Xi\langle\overrightarrow{B}\colon y\rangle \Rightarrow C\colon\chi_2}{\Xi\langle\overrightarrow{A\oplus B}\colon z\rangle \Rightarrow C\colon z \to x.\chi_1;y.\chi_2}\oplus L \qquad \frac{\Xi \Rightarrow A\colon\phi}{\Xi \Rightarrow A\oplus B\colon\iota_1\phi}\oplus R_1 \qquad \frac{\Xi \Rightarrow B\colon\psi}{\Xi \Rightarrow A\oplus B\colon\iota_2\psi}\oplus R_2$$

Figure 12 Additives

tion together are exemplified by a quantifier phrase assignment **everyone**: $(S{\uparrow}N){\downarrow}S$, simulating Montague's S14 treatment of quantifying in. Extraction and discontinuous product, $\odot$, are shown together with the continuous unit in an assignment to a relative pronoun **that**: $(CN\backslash CN)/((S{\uparrow}N){\odot}I)$, allowing both peripheral and medial extraction, as in **that John likes**: $CN\backslash CN$ and **that John saw today**: $CN\backslash CN$.

In relation to the multiplicative rules, notice how the stoup is distributed reading bottom-up from conclusions to premise: it is partitioned between the two premises in the case of binary rules, copied to the premise in the case of unary rules, and empty in the case of nullary rules (axioms).

The remaining figures give rules for additives, quantifiers, normal modalities, bracket modalities, exponentials, and limited contraction for anaphora.

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11. $$\frac{\Xi\langle\overrightarrow{A[t/v]: x}\rangle \Rightarrow B\colon \psi}{\Xi\langle\overrightarrow{\bigwedge vA\colon z}\rangle \Rightarrow B\colon \psi\{(z\ t)/x\}}\ \bigwedge L \qquad \frac{\Xi \Rightarrow A[a/v]\colon \phi}{\Xi \Rightarrow \bigwedge vA\colon \lambda v\phi}\ \bigwedge R^{\dagger}$$

12. $$\frac{\Xi\langle\overrightarrow{A[a/v]: x}\rangle \Rightarrow B\colon \psi}{\Xi\langle\overrightarrow{\bigvee vA\colon z}\rangle \Rightarrow B\colon \psi\{\pi_2 z/x\}}\ \bigvee L^{\dagger} \qquad \frac{\Xi \Rightarrow A[t/v]\colon \phi}{\Xi \Rightarrow \bigvee vA\colon (t, \phi)}\ \bigvee R$$

Figure 13 Quantifiers, where † indicates that there is no a in the conclusion

13. $$\frac{\Xi\langle\overrightarrow{A}\colon x\rangle \Rightarrow B\colon \psi}{\Xi\langle\overrightarrow{\Box A}\colon z\rangle \Rightarrow B\colon \psi\{^{\vee}z/x\}}\ \Box L \qquad \frac{\boxtimes\Xi \Rightarrow A\colon \phi}{\boxtimes\Xi \Rightarrow \Box A\colon {}^{\wedge}\phi}\ \Box R$$

14. $$\frac{\boxtimes\Xi\langle\overrightarrow{A}\colon x\rangle \Rightarrow \diamondplus B\colon \psi}{\boxtimes\Xi\langle\overrightarrow{\Diamond A}\colon z\rangle \Rightarrow \diamondplus B\colon \psi\{^{\cup}z/x\}}\ \Diamond L \qquad \frac{\Xi \Rightarrow A\colon \phi}{\Xi \Rightarrow \Diamond A\colon {}^{\cap}\phi}\ \Diamond R$$

Figure 14 Normal modalities, where $\boxtimes/\diamondplus$ marks a structure all the types of which have main connective a box/diamond

15. $$\frac{\Xi\langle\overrightarrow{A}\colon x\rangle \Rightarrow B\colon \psi}{\Xi\langle\overrightarrow{[[\,]^{-1}A\colon x]}\rangle \Rightarrow B\colon \psi}\ [\,]^{-1}L \qquad \frac{[\Xi] \Rightarrow A\colon \phi}{\Xi \Rightarrow [\,]^{-1}A\colon \phi}\ [\,]^{-1}R$$

16. $$\frac{\Xi\langle[\overrightarrow{A}\colon x]\rangle \Rightarrow B\colon \psi}{\Xi\langle\overrightarrow{\langle\rangle A}\colon x\rangle \Rightarrow B\colon \psi}\ \langle\rangle L \qquad \frac{\Xi \Rightarrow A\colon \phi}{[\Xi] \Rightarrow \langle\rangle A\colon \phi}\ \langle\rangle R$$

Figure 15 Bracket modalities

17. $$\frac{\Xi(\zeta \uplus \{A\colon x\}; \Gamma_1, \Gamma_2) \Rightarrow B\colon \psi}{\Xi(\zeta; \Gamma_1, !A\colon x, \Gamma_2) \Rightarrow B\colon \psi}\ !L \quad \frac{\zeta; \Lambda \Rightarrow A\colon \phi}{\zeta; \Lambda \Rightarrow !A\colon \phi}\ !R \quad \frac{\Xi(\zeta; \Gamma_1, A\colon x, \Gamma_2) \Rightarrow B\colon \psi}{\Xi(\zeta \uplus \{A\colon x\}; \Gamma_1, \Gamma_2) \Rightarrow B\colon \psi}\ !P \quad \frac{\Xi(\zeta \uplus \{A\colon x\}; \Gamma_1, [\{A\colon y\}; \Gamma_2], \Gamma_3) \Rightarrow B\colon \psi}{\Xi(\zeta \uplus \{A\colon x\}; \Gamma_1, \Gamma_2, \Gamma_3) \Rightarrow B\colon \psi\{x/y\}}\ !C$$

18. $$\frac{\Delta(A\colon x) \Rightarrow D\colon \omega([x]) \quad \Delta(A\colon x, A\colon y) \Rightarrow D\colon \omega([x, y]) \quad \ldots}{\Delta(?A\colon w) \Rightarrow D\colon \omega(w)}\ ?L \quad \frac{\Xi \Rightarrow A\colon \phi}{\Xi \Rightarrow ?A\colon [\phi]}\ ?R \quad \frac{\zeta; \Gamma \Rightarrow A\colon \phi \quad \zeta'; \Delta \Rightarrow ?A\colon \psi}{\zeta \uplus \zeta'; \Gamma, \Delta \Rightarrow ?A\colon [\phi|\psi]}\ ?M$$

Figure 16 Exponentials

19. $$\frac{\zeta; \Gamma \Rightarrow A{:}\,\phi \qquad \zeta'; \Delta\langle \overrightarrow{A}{:}\,x; \overrightarrow{B}{:}\,y\rangle \Rightarrow D{:}\,\omega}{\zeta \uplus \zeta'; \Delta\langle \Gamma; \overrightarrow{B|A}{:}\,z\rangle \Rightarrow D{:}\,\omega\{\phi/x, (z\ \phi)/y\}}\,|L \qquad \frac{\zeta; \Gamma\langle \overrightarrow{B_0}{:}\,y_0; \ldots; \overrightarrow{B_n}{:}\,y_n\rangle \Rightarrow D{:}\,\omega}{\zeta; \Gamma\langle \overrightarrow{B_0|A}{:}\,z_0; \ldots; \overrightarrow{B_n|A}{:}\,z_n\rangle \Rightarrow D|A{:}\,\lambda x\omega\{(z_0\ x)/y_0, \ldots, (z_n\ x)/y_n\}}\,|R$$

Figure 17 Limited contraction for anaphora

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Tense and Scope in Superlatives

Miriam Nussbaum

Abstract This paper provides new evidence that relative readings of superlatives are indefinites, as proposed by Szabolcsi (1986) and Heim (1985, 1999), based on the interaction between tense phenomena and the availability of relative readings. I show that the lack of sequence of tense forces absolute readings of superlatives, as do temporally independent interpretations of predicates. I argue that this is because the "definite article" in relative superlatives is a weak determiner, while absolute superlatives contain a true definite article that comes with its own situation pronoun (Schwarz 2009). The contrast between absolute and relative superlatives in this regard is thus an instance of Musan's Generalization (Musan 1997).

Keywords superlative · sequence of tense · definite article · relative clause · relative superlative

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1 Introduction

1.1 Absolute and Relative Readings of Superlatives

This paper is concerned with aspects of a well-known ambiguity in superlatives, namely that of *relative* versus *absolute* interpretations (Heim 1985, Szabolcsi 1986). We can observe these two readings in (1):

(1) John climbed the highest mountain.

On the absolute reading, (1) means that John climbed the highest mountain that there is in some situation (be it the highest mountain in the world, the highest mountain in the country, or perhaps the highest mountain on a certain list). The relative reading, by contrast, compares John to other people: on this reading, (1) is true if John climbed a higher mountain than any other salient individual did, and the sentence can still be true if there is an even higher mountain that was climbed by nobody.

One proposed explanation for this ambiguity is syntactic scope: that is, the interpretation depends on movement of the superlative operator. Heim (1999) gives the following LFs for the two readings of (1), and the meaning for the superlative operator in (3):

(2) a. John climbed [the [-est C] λd [d-high mountain]]
b. John [-est C] λd [climbed a d-high mountain]

(3) *-est*$(C)(D)(x) = 1$ iff $\forall y \in C[y \neq x \rightarrow \max\{d : D(d)(x) = 1\} > \max\{d : D(d)(y) = 1\}]$

According to (3), the superlative operator takes a set of alternatives (C), a gradable predicate (D), and an individual (x). A sentence containing a superlative is true iff the gradable predicate is true of the superlative's individual argument x to a higher degree than any other alternative to x in C.

In the case of the two readings of *John climbed the highest mountain*, the position of the superlative operator determines the identity of the gradable predicate and set of alternatives in question.

In (2a), the superlative will apply to the gradable predicate [$\lambda x.\lambda d.\ x$ is a d-high mountain], and C will be a set of mountains. The definite article applies to the predicate [$\lambda x.\ \forall y \in C$[max{$d$: x is a d-high mountain} > max{d: y is a d-high mountain}]], which is a predicate that is true of the mountain that is higher than every other mountain in C. The definite article applies to this predicate, and returns the unique member of C of which it is true. The sentence will end up asserting that John climbed a mountain that is higher than any other mountain. In the absence of any context (and thus of any salient option for domain restriction), this will mean that John climbed Mount Everest. This is the "absolute" reading of the superlative, referring to the highest of all mountains.

In (2b), on the other hand, the gradable predicate that *-est* C applies to will be [$\lambda x.\lambda d.\ x$ climbed a d-high mountain]. The set of alternatives C will contain salient individuals who climbed mountains. (2b) is true iff its subject, John, climbed a higher mountain than any other individual in C did. This is the "relative" reading, comparing John to other salient climbers with respect to the heights of the mountains they climbed.

Also of note is the fact that in (2b), the definite article is given an indefinite interpretation, forming the predicate [$\lambda x.\lambda d.\ x$ climbed a d-high mountain]. If it were instead interpreted as definite, (2b) would be true iff the maximal degree d such that John climbed *the* d-high mountain exceeded the maximal degree d' such that Mary climbed *the* d'-high mountain, and so on. The relative reading of (1) would then give rise to the presupposition that there was at most one mountain of any given height: a presupposition that is not, in fact, present.

Aside from being necessary to get the truth conditions of (2b) right, relative superlatives and indefinites appear to have something in common on a deeper level as well. Szabolcsi (1986) noted that superlatives with relative readings pattern with indefinites in environments that give rise to the Definiteness Effect, even though they contain (on the surface) a definite article:

(4) a. *John has the sister.
    b. John has the smartest sister.

Despite the apparent presence of the definite article, which leads to the ungrammaticality of (4a), the superlative in (4b) is acceptable on a relative superlative reading that compares alternatives to John with respect to how smart their sisters are. This has been taken as evidence that what looks like a definite in relative superlatives is actually an indefinite (Szabolcsi 1986, Heim 1999).

Some other theories of superlatives, by contrast, hold that even relative readings involve a true definite article (Farkas & É. Kiss 2000, Sharvit & Stateva 2002, Teodorescu 2009). The question of how to reconcile the indefinite-like properties of relative superlatives with the overt definite morphology is still a matter of some controversy. In this paper, I adopt a movement theory of superlatives based on Heim 1999.

In the next section, I will discuss some novel data illustrating another contrast between relative and absolute superlatives. The rest of the paper will be devoted to showing how analyzing the relative/absolute distinction as a contrast in definiteness can help solve the puzzle that these data present.

1.2 The Puzzle

For the first part of the puzzle, consider the contrast between the two sentences in (5), in the given context.[1]

(5) *Context: On a certain game show, the game ends up with each contestant receiving a box with money in it. There are 20 boxes available, each with a different amount of money inside, and 10 contestants. The top prize is a million dollars. At the end of the show, the contestants all open their boxes at the same time.*

a. Which contestant opened the box **that has the most money inside**?

b. Which contestant opened the box **that had the most money inside**?

The question in (5a) is unambiguously an absolute superlative, referring to the box with the million dollars. Since there are more boxes than contestants, the answer could be "Nobody." In (5b), this reading is available, but there is another interpretation as well. This is a relative reading, which asks which contestant won the game (that is, who opened a box with more money in it than any other contestant did).[2]

Either of the sentences in (5) could be uttered just after the game has ended, so this contrast is not about the actual times at which the predicates *box* and *have d-much money inside* hold. The issue is the effect of the expression of tense on the interpretation of the sentence. That is, we can see that the tense of the relative clause has an effect on which interpretations are available: in particular, the relative reading requires sequence of

[1]The judgments in this section are somewhat subtle and difficult, but robust. When presenting this work, I have had audience members tell me that they initially did not perceive the contrasts, but agreed with these judgments once they heard the sentences and contexts read aloud. I therefore advise slow and careful consideration of these examples on each intended reading.

[2]These are the absolute and relative readings of *the box that had the most money*, not of *the most money*. A proportional reading of *most*, paraphrasable as "the box that had more than half of the money inside" (see Hackl 2009), is also unavailable. For current purposes, we can assume that the combination of *box* with the relative clause produces the predicate *box that had d-much money inside,* which is parallel to *d-tall mountain* or *d-smart sister* with respect to its interaction with the superlative.

tense.

Similarly to the examples in (1), we can derive the two readings of (5b) by varying the scope of the superlative operator. A first approximation of the relevant LFs is given in (6) (to be revised later):

(6) John opened the box that had the most money inside.

a. Absolute reading:
PAST John open [the [box [-est C] [$\lambda d.\lambda x.$ PAST x have d-much money]]]

b. Relative reading:
PAST John [-est C] $\lambda d.\lambda y.$ y open "the"$_\exists$ [box [$\lambda x.$ PAST x have d-much money]]

With present under past, the second of these options is unavailable: only the absolute reading (referring to a particular box that contains the top prize) is possible.

(7) John opened the box that has the most money inside.

a. Absolute reading:
PAST John open [the [box [-est C] [$\lambda d.\lambda x.$ PRES x have d-much money]]]

b. Relative reading (unavailable):
***PAST** John [-est C] $\lambda d.\lambda y.$ y open "the"$_\exists$ [box [$\lambda x.$ **PRES** x have d-much money]]

A similar phenomenon occurs when the superlative contains a time-sensitive predicate:

(8) Who married the tallest first-grader?

The sentence in (8) can be a way of asking about a particular person: if John was the tallest member of the salient first-grade class several decades ago, even if some former classmates are currently taller than him, (8) can be interpreted as a question about who married John (an absolute reading). The sentence also has some implausible readings, where a marrying event took place while a participant was still in first grade. These readings are not so interesting, and can be ignored.

The striking fact about (8), however, is that the relative analogue of the first reading is unavailable. (8) cannot be understood to mean "Who married someone whose height in first grade exceeded the first-grade heights of the people that everyone else married?" That is, if the predicates *marry* and *first-grader* are to be interpreted with respect to different times, the superlative must be interpreted as absolute.

1.3 Upstairs *De Dicto* Readings

Another facet of the question of the relative/absolute distinction arises in intensional contexts. A sentence like (9) has a total of five readings; the first four of them are sketched below, along with an LF according to the movement theory and a paraphrase.

(9) John wants to climb the highest mountain. (Based on Heim 1999)

a. Absolute, *de dicto*:
John wants [PRO to climb [the [[-est C] [$\lambda d.\lambda x.\ x$ is a d-high mountain]]]]
'John wants to climb whichever mountain is the highest.'

b. Absolute, *de re*:
[the [-est C] [$\lambda d.\lambda x.\ x$ is a d-high mountain]] λ_2 John wants [PRO to climb t_2]
'John wants to climb a particular mountain, which is the highest.'

c. Relative, *de dicto*:
John wants [PRO [-est C] λd to climb "the"$_\exists$ $\lambda x.\ x$ is a d-high mountain]
'John wants to be the person who climbs a higher mountain than anyone else climbs.'

d. Relative, *de re*:
John [-est C] λd ["the"$_\exists$ $\lambda x.\ x$ is a d-high mountain] λ_2 wants [PRO to climb t_2]
'The mountain that John wants to climb is higher than the mountain that anyone else wants to climb.'

The fifth reading, the so-called "upstairs *de dicto* reading," is the one that we will primarily focus on here:

(10) Upstairs *de dicto* reading of (9):
John [-est C] λd wants [PRO to climb "the"$_{\exists}$ $\lambda x.\ x$ is a d-high mountain]
'John's desires with respect to how high a mountain he climbs are more exacting than anyone else's.'

More specifically, the upstairs *de dicto* reading describes a situation where John and his comparison-class cohorts do not have particular mountains in mind that they want to climb. Rather, their desires are about mountain heights: if John wants to climb a mountain that is at least 5000 feet high, Mary wants to climb a mountain that is at least 4000 feet high, and Bill wants to climb a mountain that is at least 3000 feet high, then the sentence is true on this reading. John also does not have any desires about Mary or Bill in this scenario: he does not want to beat them by climbing a higher mountain (as he does in the *de dicto* relative reading), but merely has a stronger desire about how high a mountain he will climb.

In the upstairs *de dicto* reading, the superlative operator has moved to a position outside of the embedded clause, while the DP from which it came remains inside. This contrasts with the other two relative readings – where the superlative operator and the predicate *d-high mountain* are both inside the embedded clause (*de dicto*) or both move out (*de re*) – and with the absolute readings, where the superlative operator is part of a definite DP along with the gradable predicate.

As we can see from the LFs above, the movement theory provides an account of how upstairs *de dicto* readings are possible, by allowing the superlative operator and the associated predicate to be separated by a clause boundary. Non-movement theories tend to have difficulty accounting for upstairs *de dicto* readings (though see Sharvit & Stateva 2002 for one attempt to do so).

Bylinina et al. (2014) provide further support for a movement theory of superlatives by contrasting the behavior of superlatives with that of ordinals in these intensional contexts:

(11) a. John wants to take the earliest train.
b. John wants to take the first train.

As Bylinina et al. point out, (11b) lacks an upstairs *de dicto* reading. That is, (11a) is true and (11b) is false in a scenario like the one described above for (10) (one where John's desires about how early a train he takes are stronger than Mary's or Bill's, but he doesn't have a particular train in mind and he isn't including Mary and Bill in his deliberations). According to Bylinina et al., this suggests that the superlative operator can move out of its clause, while ordinals must be interpreted *in situ*.

Our two examples from section 1.2 each show us something interesting when we embed them in contexts like (9). We turn first to the phenomenon of sequence of tense in relative clauses:

(12) *Context: The same game show as before. The boxes have been filled with various amounts of money and hidden, and the game is about to start. Before they play the game, the contestants are interviewed. The interviewer asks them, among other things, about the amount of money they hope to win. John is the most ambitious of the contestants: he says that he hopes to win at least $50,000, while the other contestants each say that they hope to win at least $10,000 or $20,000. Later in the show, once the game has been going on for a while, the announcer summarizes what was said in the interviews:*

a. (At the beginning of the game,) John hoped to open the box that had the most money inside.

b. #(At the beginning of the game,) John hoped to open the box that has the most money inside.

The sentences in (12) show the same contrast that the unembedded examples in the previous section did: in order to be interpreted on the intended reading from the given context (that is, the upstairs *de dicto* reading), the relative clause containing the superlative must obey sequence of tense. With present under past, the only available readings are the absolute ones, where John hopes to open the million-dollar box.[3]

Similarly, a time-sensitive predicate can be interpreted independently on an absolute reading, but not a relative reading. The paraphrases of

[3]More specifically, these readings are the *de dicto* absolute reading (where in each of John's desire-worlds, he opens the box that has the most money in that world) and the *de re* absolute reading (where John wants to open a particular box, and that box is the one with the most money in it).

each of the readings are given below; the LFs are analogous to those in (9).

(13) John wants to marry the tallest first-grader.

a. 'John wants to marry whoever is/was the tallest first-grader.' (Absolute, *de dicto*)

b. 'John wants to marry a particular person, who is/was the tallest first-grader.' (Absolute, *de re*)

c. 'John wants to be the person who marries a taller (#former) first-grader than anyone else does.' (Relative, *de dicto*)

d. 'The (#former) first-grader that John wants to marry is taller than the first-grader anyone else wants to marry.' (Relative, *de re*)

e. 'John has the strongest requirements for the minimum height of the (#former) first-grader he marries.' (Upstairs *de dicto*)

In other words, the absolute readings allow the predicate *first-grader* to be interpreted as 'former first-grader', while the relative readings force *first-grader* to be interpreted at the same time as either *want* or *marry* (due to the semantics of *want*, the *marry*-time is in the future with respect to the matrix time). What is interesting about this contrast is that it falls out not according to whether the DP is interpreted *de dicto* or *de re*, but according to whether the superlative has a relative or absolute interpretation.

In sum, searching for upstairs *de dicto* readings in both of these contexts has reinforced the puzzle: relative readings systematically differ from absolute readings, in a way that cross-cuts distinctions of intensionality.

To answer the question of why relative readings in finite relative clauses require sequence of tense, and why relative readings are unavailable when a noun like *first-grader* is modified by a superlative, some investigation of the relevant properties of definites and of tense is in order. We will look at definiteness in section 2, and move on to tense in section 3.

2 The Differences between Strong and Weak NPs

2.1 Musan's Generalization

Definiteness is well known to have an effect on the temporal (and modal) interpretation of NPs (Musan 1997, Keshet 2008). Specifically, the interpretative possibilities available for *weak* (existential) determiners are more limited. This phenomenon is known as Musan's Generalization.

(14) Musan's Generalization:
A noun phrase can be temporally independent if and only if it is strong. (Keshet 2008:42)

Determiners like *three* and *many* can have either a strong or a weak construal. The weak interpretation is forced in existential environments like the Existential *There* Construction. The contrast between the strong and weak versions of *three* in (15) and *many* in (16) illustrates the effect of Musan's Generalization.

(15) Some politicians knew each other in college. In fact,
a. three U.S. senators were attending Harvard together in 1964.
b. #there were three U.S. senators attending Harvard together in 1964.

(16) The professors in this department are quite young. In fact,
a. many professors were in kindergarten in the 1980s.
b. #there were many professors in kindergarten in the 1980s.
(Keshet 2008:42)

If the determiner receives a weak interpretation, the NP cannot be independent, and must inherit its evaluation world and time from the matrix clause. This leads to the observed oddness of the weak version, since the only available interpretation of (16b) is one where *professor* and *in kindergarten* are true of the same individuals at the same time.[4]

2.2 Situations and Determiners

Schwarz (2009) proposes to explain Musan's Generalization by giving

[4] *Three* and *many* are useful for illustrating the contrast, since they allow either a strong or a weak construal. DPs that are obligatorily weak seem to be rare, though bare plurals do show the effect outside of the Existential *There* Construction:

(i) #Professors were in kindergarten in the 1980s.

According to the analysis of relative superlatives that I am pursuing in this paper, they constitute a second example of a DP that is always weak.

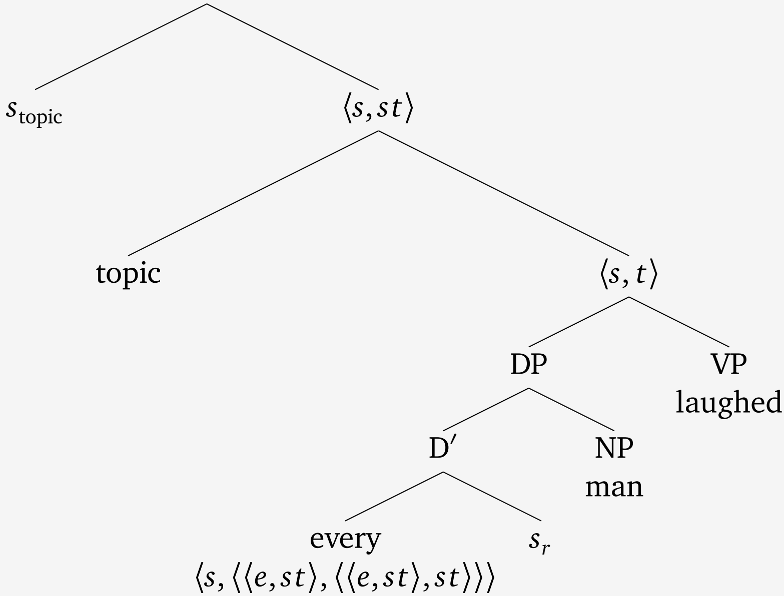


Figure 1 Schwarz's (2009) structure for *every* (somewhat simplified)

strong determiners an extra argument slot for a resource situation pronoun, as shown in figure 1.

The lexical entry for *every* is given in (17):

(17) $[\![\text{every}]\!] = \lambda s_r \in D_s.\lambda P \in D_{\langle e,st \rangle}.\lambda Q \in D_{\langle e,st \rangle}.\lambda s.\forall x[P(x)(s_r) \rightarrow Q(x)(s)]$ (Schwarz 2009:95)

A strong determiner like *every* takes a resource situation pronoun as its first argument (which can be either bound or free), and the restrictor is evaluated with respect to this situation. Thus, it is possible for the restrictor and scope of a strong determiner to be evaluated with respect to different situations.

A weak determiner, on the other hand, does not take a situation argument, as shown in figure 2. The weak determiner *a* takes two properties, both of which are evaluated with respect to the topic situation. For *a man laughed* to be true, there must be an individual who both laughed and is a man in that same situation.

The differences between absolute and relative superlatives with respect to their definiteness behavior suggest that the definite article in absolute

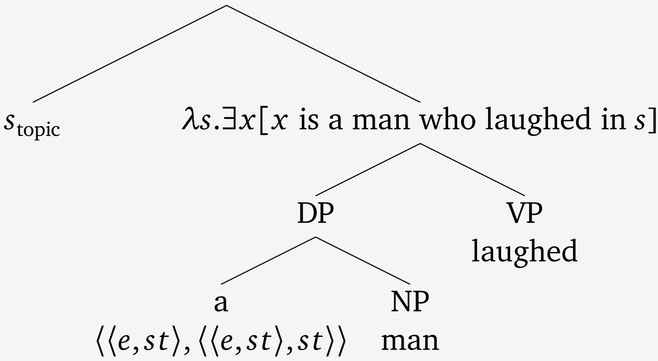


Figure 2 Schwarz's (2009) structure for the indefinite article

superlatives patterns with other strong determiners in having a situation pronoun argument. This allows the predicates in the NP part of the superlative to be interpreted separately from the matrix, unlike with the existentially-interpreted version of the definite article that we find in relative superlatives. In order to explain the phenomenon of sequence of tense in relative clauses, we will next investigate the question of what role is played by tense itself.

3 Topic Situations and Times

3.1 Tense Pronouns

Kratzer (1998) analyzes sequence of tense as a consequence of the presence of a "zero" tense. The analogy is with bound indexical pronouns like the ones in (18):

(18) a. Only I got a question that I understood.
b. Only I think that Mary will invite me.
c. Only I considered the question of whether I should leave before I got bored.

These sentences have strict readings, where the lower instance of the first-person pronoun refers to the speaker; however, they also have sloppy readings, paraphrasable as "Only I am an x such that x got a question x understood," and so on. On Kratzer's view, these instances of *I* are zero pronouns: they start out with no ϕ-features, but receive them through a process of feature transmission when bound by a local antecedent. This is how it can be possible for a bound pronoun to be pronounced as *I*.

Kratzer proposes that in addition to zero pronouns, there are also zero tenses: that is, English has indexical present and past tenses, as well as a zero tense that must be bound by a local antecedent. If one of these zero tenses appears in a finite clause, it can receive features from its antecedent and be pronounced like an ordinary tense morpheme (just like a zero personal pronoun that ends up being pronounced as *I*).

The inventory of tenses according to Kratzer's analysis is given in (19). Kratzer gives them the type *i*, and has aspect phrases take them as arguments to form propositions.

(19) Kratzer's (1998:101) inventory of tenses:

a. $[\![\textsc{present}]\!]^{g,c}$ is only defined if c provides an interval t that includes t_0 (the utterance time). If defined, then $[\![\textsc{present}]\!]^{g,c}$ = t.

b. $[\![\textsc{past}]\!]^{g,c}$ is only defined if c provides an interval t that precedes t_0. If defined, then $[\![\textsc{past}]\!]^{g,c}$ = t.

c. $[\![\varnothing_n]\!]^{g,c} = g(n)$

That is, (nonzero) tenses refer to time intervals given by the context, and introduce presuppositions about those intervals. This is similar to how personal pronouns refer to salient individuals in the context, and may introduce gender presuppositions.

3.2 The Relationship between Situations and Tenses

Armed with a way of dealing with both indexical tenses and sequence of tense, we can now explain the sequence of tense contrast in superlatives. I will assume that the topic situation of the clause comes in with the tense operator, which takes it as an argument. The output is an object which, like one of Kratzer's tenses in (19), refers to an interval.

(20) a. $[\![\textsc{present}]\!]^{g} = \lambda s\colon \tau(s) \supseteq t_0.\ \tau(s)$

b. $[\![\textsc{past}]\!]^{g} = \lambda s\colon \tau(s) < t_0.\ \tau(s)$

That is, the nonzero tense PRESENT or PAST takes a situation and returns the time interval associated with it, introducing the presupposition that the situation (respectively) includes or precedes the utterance time. As

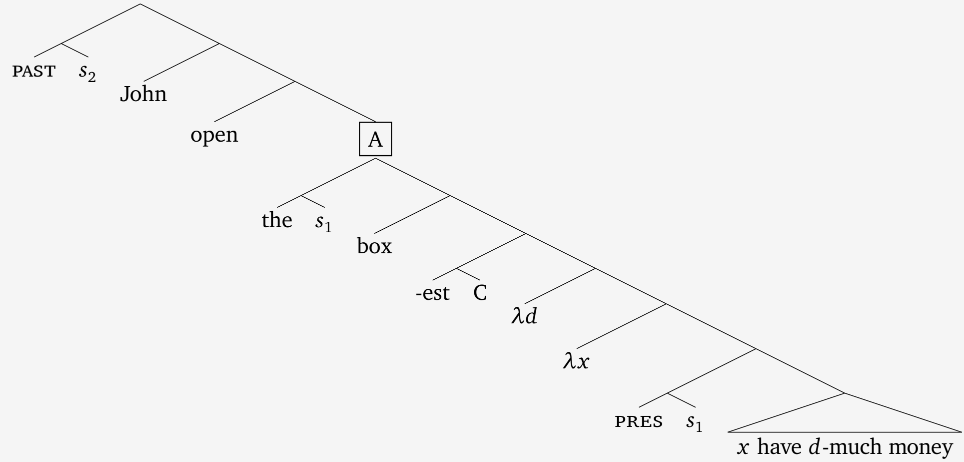


Figure 3 LF of an absolute superlative with present under past

in Kratzer's original proposal, a zero tense is bound by the closest higher tense and inherits its features.

We can now see how present under past in an absolute superlative is derived. The lexical entry for the strong determiner *the* is given in (21):

(21) $[\![\text{the}]\!] = \lambda s.\lambda P_{\langle e,st\rangle} : \exists! x[P(x)(s)].\iota x.P(x)(s)$ (Schwarz 2009:148)

The LF for the sentence *John opened the box that has the most money inside* is shown in figure 3. The constituent marked $\boxed{\text{A}}$ is a definite DP. Its interpretation is given in (22):

(22) $[\![\boxed{\text{A}}]\!] = \iota x.x$ is a box in s_1 & $\forall y \in C[x \neq y \rightarrow x$ has more money in s_1 than $y]$
Presupposition of the definite article: there is exactly one such box.
Presupposition of PRES: the runtime of s_1 contains t_0.

The head NP *box* and the relative clause combine by Predicate Modification. According to Keshet's (2008) Intersective Predicate Generalization – a more general version of Musan's Generalization – this means that they must be interpreted with respect to the same situation. The sentence is true iff at some past time t_2, John opened the unique box that that currently (during some span of time t_1 that includes the utterance time) con-

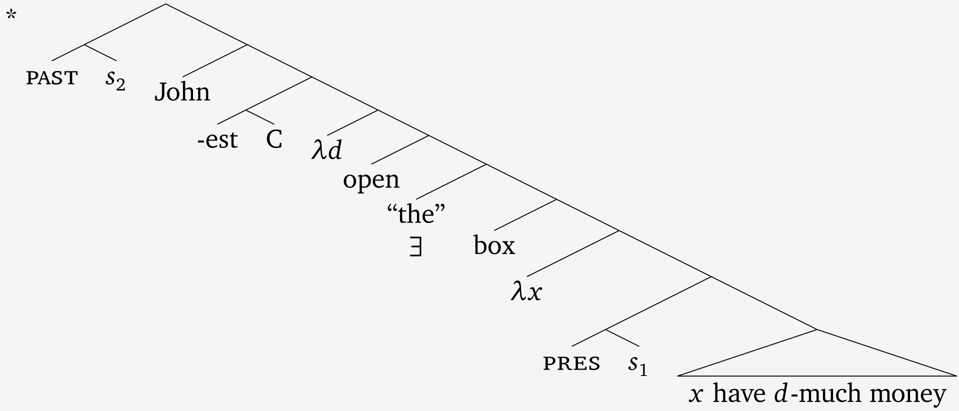


Figure 4 Tense conflict leads to the unavailability of a relative reading

tains more money than any other box currently contains (at t_1). It is possible to derive this interpretation because the strong determiner comes with a situation argument that can be coindexed with the situation argument of the tense of the relative clause.

The LF for the unavailable relative reading of a superlative with present under past is given in figure 4. Again, *box* is combining with the relative clause by Predicate Modification, which means that they must be interpreted with respect to the same situation. However, the next situation pronoun above *box* is the one associated with the matrix PAST. The situations s_1 and s_2 must be different, because of the presuppositions of the tense operators: PAST presupposes that its situation argument is temporally located before the utterance time, while PRESENT presupposes that the runtime of its situation argument includes the utterance time. Thus, the head noun *box* and the relative clause cannot be interpreted with respect to the same situation, violating the Intersective Predicate Generalization. Unlike the case of the absolute superlative above, *box* has no strong determiner above it, and thus no alternative for a situation of evaluation.

In order for a relative reading to be possible, the tense of the relative clause will have to be a zero tense bound by the matrix tense, as shown in figure 5. This zero tense receives its pronunciation and features from its antecedent, resulting in sequence of tense. Here, both the relative clause and the head noun *box* are evaluated with respect to the matrix situation s_2, and the Intersective Predicate Generalization is not violated. The sen-

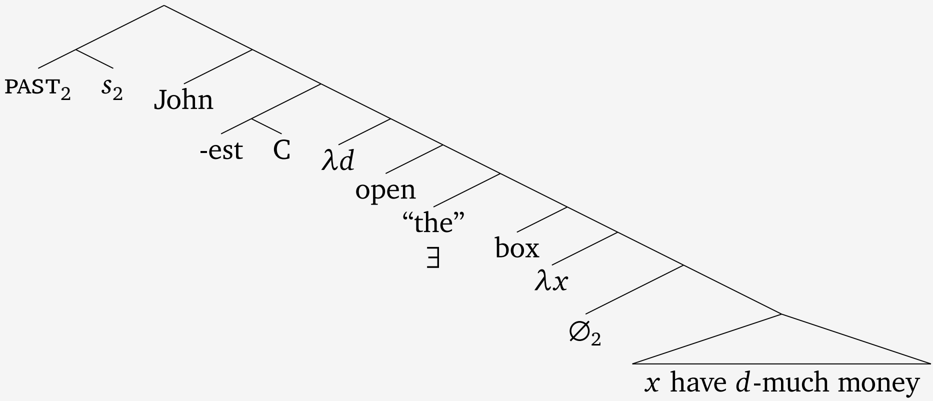


Figure 5 Relative reading with bound tense

tence is true iff at some time t_2 (which precedes the utterance time), for all x in the comparison class C who are not John, the (maximal) amount of money in the box that John opened at t_2 is larger than the (maximal) amount of money in the box that x opened at t_2.

The derivation of a relative reading in an intensional context (as in section 1.3) is shown in figure 6. Since the embedded clause is non-finite, it does not have a tense of its own, and depends on the matrix tense for its interpretation. As in the unembedded example in figure 5, the relative clause contains a bound zero tense, which results in the appearance of past tense morphologically; present tense in the relative clause would result in the same conflict that arose before. Thus, relative clauses of this kind must obey sequence of tense if they are to give rise to relative readings, regardless of whether they appear in matrix or embedded clause positions.

3.3 Temporally Independent Relative Clauses

At this point, it should be noted that although relative clauses combine with their head nouns by Predicate Modification, finite relative clauses have been observed to allow some temporally independent interpretations, as illustrated in (23).

(23) There were many professors who were in kindergarten in the 1980s at the conference.

The first thing to notice about (23) is that the relative clause contains

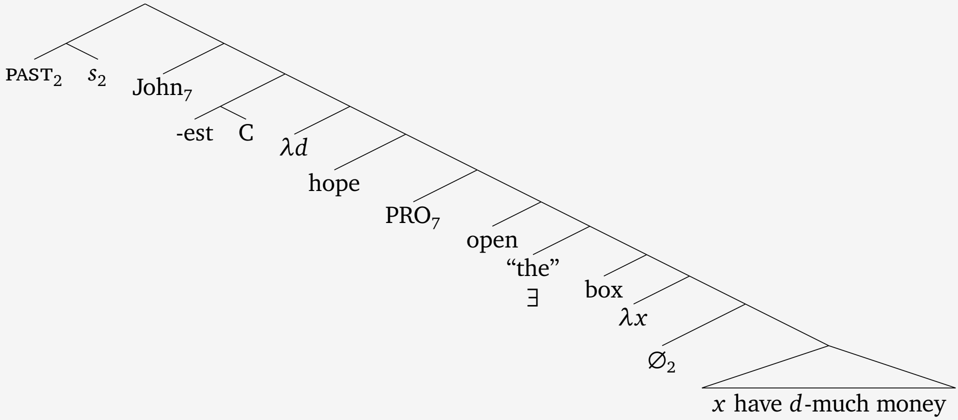


Figure 6 Upstairs *de dicto* reading of *John hoped to open the box that had the most money*

an overt temporal expression, without which an independent reading is impossible:

(24) #There were many professors who were in kindergarten at the conference.
(Intended reading: 'There were many professors at the conference who had been in kindergarten at some point.')

Following Kusumoto (2005) and Keshet (2008), the possibility of a temporally independent interpretation can be explained by giving the relative clause an indexical tense operator above its overt tense. In the case of (23), this tense operator will refer to the topic time of the sentence (i.e., the time that the professors were at the conference), and thus the relative clause can undergo Predicate Modification with *professors*. The resulting predicate will be one that is true of individuals who are professors at the topic time, and who (also at the topic time) have the past property of having been in kindergarten in the 1980s.

Based on the contrast between (23) and (24), I assume that it is the overt temporal expression itself that allows for the insertion of the indexical tense operator.[5] Importantly, the superlative examples central to the

[5]Kusumoto (2005:325) also discusses "later than matrix" readings of relative clauses, such as the following:

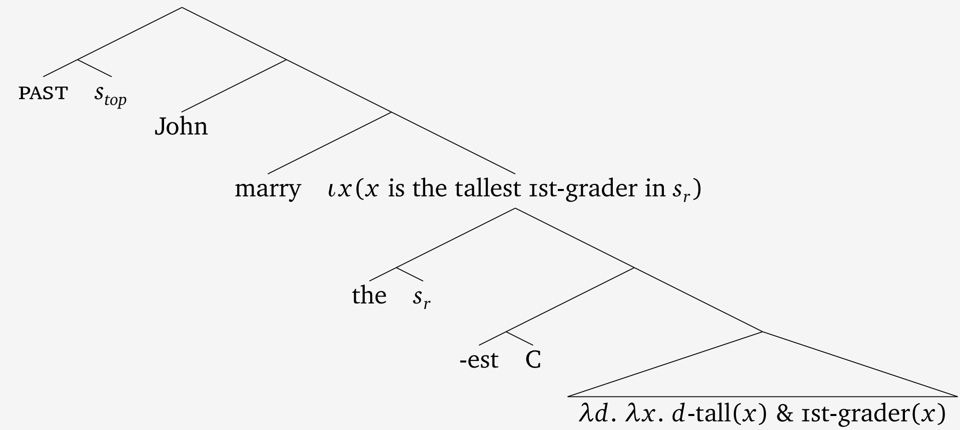


Figure 7 LF of the absolute reading of *John married the tallest first-grader*

present paper do not have overt temporal expressions; on these assumptions, then, the incompatibility of present under past with the relative construal is still expected.

3.4 Contrasts other than Sequence of Tense

Like the cases of superlatives inside relative clauses, the interaction between temporally independent interpretations and the possibility of relative readings can be explained by the presence or absence of a situation pronoun on the determiner. The absolute reading of *John married the tallest first-grader* is illustrated in figure 7.

The direct object of *marry* here is a definite DP that refers to the individual in s_r (the situation corresponding to the first argument of *the*) who is a first-grader taller than any other first-grader in s_r. So if we set s_r to be located 20 years ago, and the topic situation to be last week, we can derive the intended temporally independent reading. On this reading, the sentence is true iff last week, John married the person who was the tallest in their first-grade class 20 years ago.

If we try to derive a temporally independent relative reading, we run

(i) Hillary married a man who became the president of the U.S.

This example has no overt temporal expression, but an independent interpretation of the relative clause is still possible. Here, I assume that a verb like *become* can also introduce a tense operator for the relative clause.

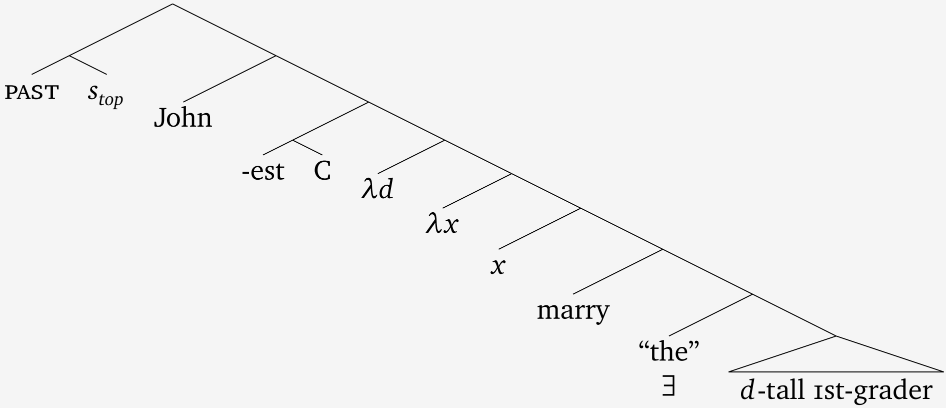


Figure 8 Implausible relative reading of *John married the tallest first-grader*

into the same problem as before: the lack of an extra situation pronoun argument for the determiner means that the predicate *first-grader* must be interpreted with respect to the same time as the main verb (in accordance with Musan’s Generalization). Thus, the only available relative reading is an implausible simultaneous one.

The situation with the upstairs *de dicto* reading, shown in figure 9, is the same as the matrix relative reading. Since the weak DP does not have its own situation pronoun, the predicate *first-grader* is again interpreted with respect to the same time as *marry*, likewise resulting in an implausible simultaneous reading.

Let us next consider superlatives that are hosted in a modifier smaller than a full relative clause. (25c) is analogous to our earlier relative clause examples, but the superlative is inside a PP modifier rather than a finite clause.

(25) a. Which contestant opened the box that had the most money inside?
b. Which contestant opened the box that has the most money inside?
c. Which contestant opened the box **with the most money inside**?

In (25c), both the absolute and relative readings are available. The relative

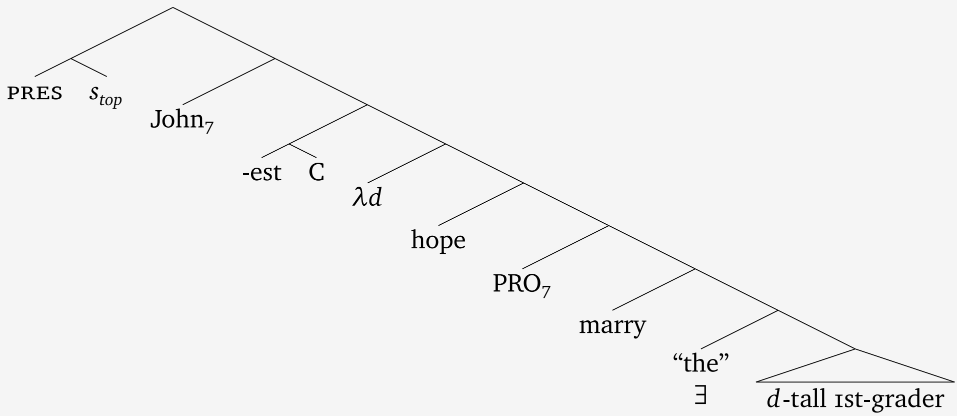


Figure 9 Implausible upstairs *de dicto* reading of *John wants to marry the tallest first-grader*

reading is unsurprising: Szabolcsi (1986) observed that superlatives have no trouble scoping out of non-finite clauses. The question is how to get the absolute reading.

Ogihara (1994) points out that relative clauses whose tense matches that of the matrix can have either a simultaneous or an independent reading:

(26) John met a man who was holding a book in his hand.

a. Simultaneous reading: The man was holding a book in his hand at the time of John's meeting him.
b. Independent reading: The man was holding a book in his hand at some other salient past time.

If we change Ogihara's example to a reduced relative or PP modifier, we find that only the simultaneous reading is possible:

(27) a. John met a man holding a book in his hand.
b. John met a man with a book in his hand.

However, if the NP hosting the reduced relative is definite, both readings are available again:

(28) John met the man holding a book in his hand. / John met the man

with a book in his hand.

a. Simultaneous reading: John met the salient man who had a book in his hand at the time.
b. Independent reading: John met the man who had a book in his hand at some other salient past time (e.g., in that picture I'm pointing to).

This is an instance of a more general method of interpretation for definites: as shown in (29), definite descriptions can be temporally shifted and used anaphorically.

(29) When I last visited my friend, he had two children: a six-year-old and a ten-year-old. **The six-year-old** graduated from medical school two years ago. (Keshet 2008:159)

The definite description can refer to an individual who was a six-year-old at a particular past time, which precedes the matrix topic time (which, in this case, is located two years before the utterance time). Similarly, the independent reading of (28) comes about if the situation argument of the definite article differs from the topic situation.

The LFs for *John opened the box with the most money inside* are given in figures 10 and 11. Similarly to the earlier examples, the absolute reading refers to the box that has more money in it than any other box in the situation s_r. (In the context we have been considering for this sentence, s_r is the same as the topic situation of the clause.) The meaning of the relative reading can be computed in the same way as in a full relative clause with a zero tense; the lack of tense in this case has the same effect.

4 How to Scope Out of a Relative Clause

I have proposed to explain the behavior of superlatives in relative clauses based on movement of the superlative operator to a position outside of the relative clause. This seems to conflict with the idea that relative clauses are scope islands. However, there is evidence that not all relative clauses are the same in this respect, and thus that a scope-based analysis of these relative readings is still tenable.

According to Hulsey & Sauerland (2006), there are two types of relative clauses in English: the *raising* structure and the *matching* structure. These

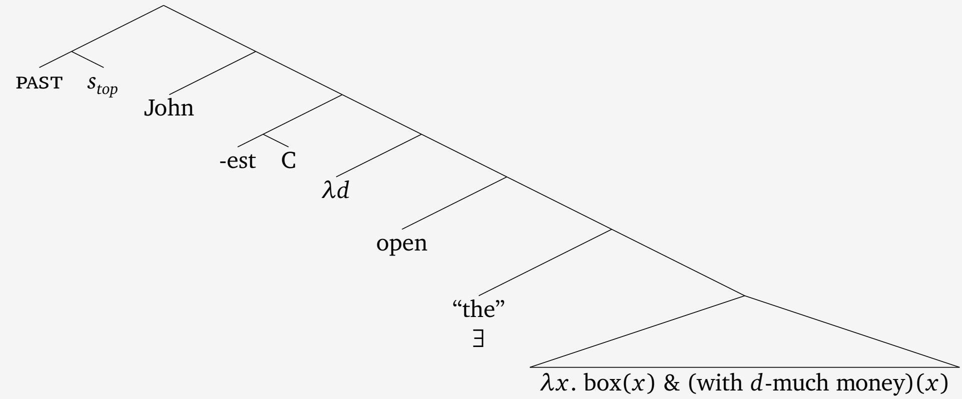


Figure 10 Relative reading of *John opened the box with the most money inside*

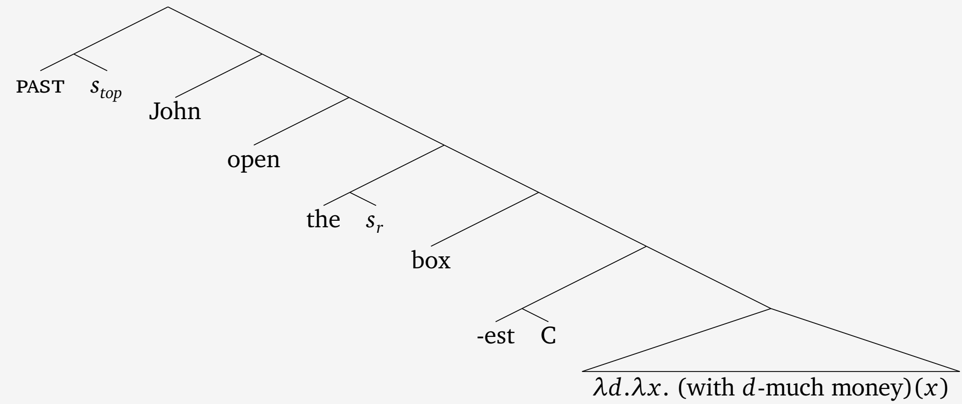
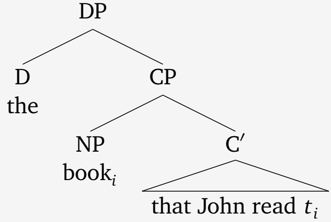


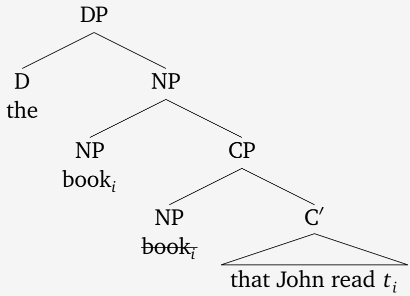
Figure 11 Absolute reading of *John opened the box with the most money inside*

two possible structures of the DP *the book that John read* are shown in (30).

(30) a. Raising:



b. Matching:

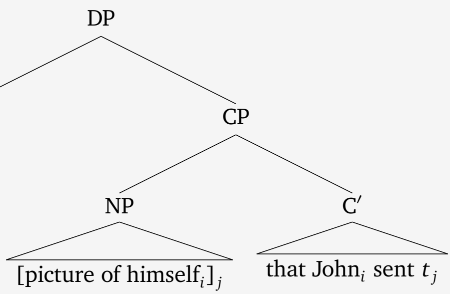


The raising relative clause in (30a) has one copy of the head NP *book*, which originates inside the relative clause. A matching relative clause, by contrast, has two separate instances of the head NP, one inside and one outside.

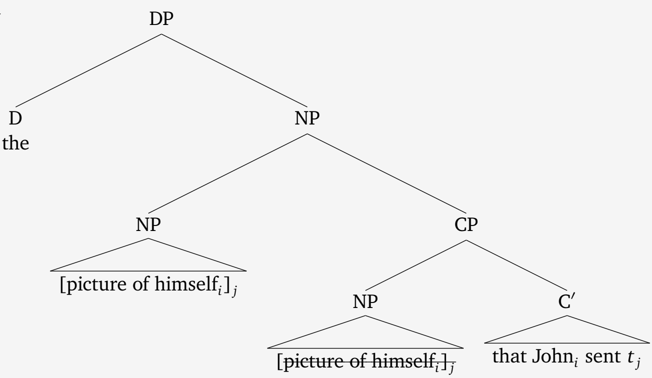
The raising structure is necessary for certain variable binding configurations, such as the one in (31).

(31) a. Mary liked [the picture of himself$_i$ that John$_i$ sent].

b. Raising:



c. Matching: *



In the raising structure in (31b), *John* can bind *himself*. This is not possible in a matching structure, ruling out that parse.

Hulsey & Sauerland also point out that if *John* in (31) is replaced with a quantifier, it can take wide scope. Thus, (32a) has the LF in (32b):

(32) a. Mary liked [the picture of himself$_i$ that every boy$_i$ sent].
b. every boy λy. Mary liked [the λx. y sent the$_x$ picture of y][6]

That is, (32a) has a reading where for every boy y, Mary liked the picture of y that y sent. In order to get this reading, rather than a reading where there is a single object that is a picture of every boy, *every boy* must outscope the definite in which it originates. Therefore, Hulsey & Sauerland argue, raising relative clauses are not islands for Quantifier Raising: an individual quantifier such as *every boy* can QR to a position outside the relative clause.

The matching analysis, on the other hand, is needed for extraposition. When the relative clause is extraposed, the variable binding configuration in (31) is no longer possible, as shown in (33).

(33) a. I saw the picture of himself$_i$ that John$_i$ liked.
b. *I saw the picture of himself$_i$ yesterday that John$_i$ liked.

This is because matching relative clauses are the kind of constituent that can undergo Late Merge, and raising relative clauses are not. In a matching structure, the relative clause is an adjunct to the head NP; in a raising structure, by contrast, the head NP is the specifier of a CP whose head is inside the relative clause. Furthermore, the head NP originated inside the relative clause, making it impossible for the relative clause to be Merged later than the head NP. Thus, if extraposition requires Late Merge (Fox & Nissenbaum 2000), then only matching relative clauses should be able to be extraposed.

As shown in (34), there is no problem with extraposition per se:

(34) I saw the picture of Bill yesterday that John liked.

The trouble with (33b) is that the binding configuration requires the rais-

[6] The subscripted *the* here is a shorthand: 'the$_x$ picture' is equivalent to 'the λy. $x = y$ and picture(y)'.

ing analysis, while the extraposition of the relative clause requires matching. The incompatibility of these requirements rules out (33b).

What does all of this mean for *the box that had the most money inside*? If the relative clause here is a scope island, then it should be impossible to move the superlative operator in the way that I have proposed. Therefore, if the mechanism I have been using to derive relative readings is correct, then the relative clause that we see in this example must be the kind of relative clause that allows QR outside of it (i.e., the raising structure).

One complication that arises here is that not all superlatives in relative clauses can have relative readings. Shimoyama (2014:316) presents the data in (35) to illustrate an apparent scope-island effect with relative clauses:

(35) *Context: A diagram consisting of numbered triangles and circles of various sizes.*

a. Triangle 1 touches the largest circle.
b. Triangle 1 touches the circle that is largest.

Somewhat surprisingly given the data that we have seen so far in this paper, (35b) lacks a relative reading, in contrast to (35a). In a situation where Triangle 1 is touching a larger circle than any other triangle is, but there is an even bigger circle in the diagram that is not touching anything, (35b) is judged to be false.

Other variants of (35b) with relative clauses show the same lack of a relative reading:

(36) a. Triangle 1 touches the circle that is the largest.
b. Triangle 1 touches the circle that is the largest circle.

I do not have an answer to the question of why this should be. However, the sentences from earlier in this paper that allow relative readings out of relative clauses differ from (35b) and its variants in one particularly salient way: in these new examples that have no relative readings available, the verb of the relative clause is *be*. If the predicative structure of this particular relative clause imposes other constraints on its syntax, this could help explain why QR is blocked here.

Turning back now to sentences like *Who opened the box that had the* *most money inside?*, we have seen that the relative reading requires a raising structure for the relative clause. The prediction of the analysis I have proposed is that extraposition of this relative clause should make the relative reading unavailable.

(37) Who opened the box by accident that had the most money inside?

This prediction is indeed borne out: (37) only has an absolute reading, even though the tense of the relative clause matches the matrix. Like the combination of extraposition and binding in (33b), the conflicting constraints on the relative clause block the relative reading. The absolute reading, which does not require QR out of the relative clause, is still available.

Hulsey & Sauerland also point out that not everything is capable of scoping out of a relative clause: individual quantifiers like *everyone* can do so, but verbs like *believe* cannot. The facts discussed in this section suggest that the superlative operator *-est* resembles individual quantifiers in its ability to undergo QR out of a relative clause, as long as the relative clause in question has a structure amenable to QR.

5 Conclusion

Among the differences between relative and absolute readings of superlatives are several contrasts related to definiteness, which have been interpreted to suggest that relative superlatives contain a “fake” definite article that has an indefinite interpretation. In this paper, I have presented some further phenomena that follow the same pattern: relative readings of superlatives in relative clauses require sequence of tense, while predicates modified by relative superlatives must receive a simultaneous interpretation. Absolute superlatives, by contrast, allow for tense mismatching (present under past) and temporally independent interpretations. I have argued that these effects can be explained by the fakeness of the fake definite article: unlike the real definite article, which is a strong determiner, the indefinitely-interpreted version of the definite article that appears in relative superlatives lacks the extra situation argument that would allow its restrictor to be interpreted independently from its scope.

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Wh-Licensing in Japanese Right Dislocations: An Incremental Grammar View

Tohru Seraku • Akira Ohtani

Abstract This paper defends an incremental grammar, a syntax model which reflects left-to-right parsing, by exploring Right Dislocations (RDs) in Japanese. We offer new data on the licensing pattern of a *wh*-phrase as the RD part, showing how the pattern follows from the way an RD string is parsed in real time. The account is also supported by other sets of data (e.g., island sensitivity). Our grammar is formalised in Dynamic Syntax.

Keywords *wh*-phrase · case-marking · island sensitivity · Dynamic Syntax

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1 Introduction

Some attempts have recently been made to reflect "parsing incrementality" in a language model, where a structure is built up as a string of words is parsed left-to-right online (Cann et al. 2005, Chung 2008, Phillips 2003, among others). This paper aims at contributing to this research paradigm by investigating Right Dislocations (RDs) in Japanese.

Japanese is prescriptively verb-final as in (1a), but elements may be placed postverbally in colloquial speech. In (1b), the object NP *sushi-o* appears after the verbal element *tabe-ta-yo* 'ate'.[1]

(1) a. Ken-ga sushi-o tabe-ta-yo.
Ken-NOM sushi-ACC eat-PAST-FP
'Ken ate sushi.'

b. Ken-ga △ tabe-ta-yo, **sushi-o**.
Ken-NOM eat-PAST-FP sushi-ACC

[1] The following glosses are used in this article: ACC accusative case particle, FP final particle, NMNS nominaliser, NOM nominative case particle, PAST past tense marker, Q question marker, TOP topic particle.

We will refer to the postverbal position as the RD part. The gap is theory-neutrally notated with Δ, and *yo* is a final particle (FP) used in casual speech. We use the term "RD" purely for descriptive purposes; in particular, "dislocation" does not entail any movement operations in the formation of RD strings.

A distinctive feature of Japanese RDs is that a *wh*-phrase cannot occur as the RD part (Kuno 1978:71).

(2) a. Ken-ga nani-o tabe-ta-no?
Ken-NOM what-ACC eat-PAST-Q
'What did Ken eat?'

b. *Ken-ga Δ tabe-ta-no, **nani-o**?
Ken-NOM eat-PAST-Q what-ACC

In the literature on Japanese RDs (e.g., Abe 1999, Endo 1996, Inoue 1978, Sells 1999, Soshi & Hagiwara 2004, Takano 2014, Takita 2014, Yamashita 2011), the licensing of a *wh*-phrase as the RD part has not been a centre of enquiry. Takano (2014), Takita (2011), Tanaka (2001), and Whitman (2000) handle the problem at some length, but section 2 offers data that may challenge these analyses.

To make a case for an incremental grammar account, we put forward a new analysis of Japanese RDs in terms of left-to-right parsing. The gist of our analysis is: *wh*-licensing reflects linear parsing, modelled as "monotonic structure building." Pre-theoretically, in (2b), when *Ken-ga tabe-ta-no* is parsed, a structure has been built up which represents a polar question. At the time of parsing *nani-o,* however, the structure is in need of modification to represent a *wh*-question. This violates the monotonicity of structure update.

Our incremental account will be formalised in Dynamic Syntax (Cann et al. 2005), a grammar formalism that, unlike other theories (e.g., Phillips 2003), strictly requires monotonicity of structure update (see section 3). Once the account is formalised, precise predictions will be made for a wide range of RD issues, including the wh-licensing pattern and island sensitivity (see sections 4–5).

2 Previous Studies

To begin with, the intonation pattern of RD strings need to be clarified. For this purpose, consider the string in (3).

(3) Ken-ga tabe-ta-yo sushi-o.
Ken-NOM eat-PAST-FP sushi-ACC
'Ken ate sushi.'

This string is interpreted as an RD example in (1b). It is, however, possible to construe (3) as a non-RD sequence that consists of two separate strings: *Ken-ga tabe-ta yo* and the fragmentary sentence *sushi-o*. Though this interpretation is possible, our concern is the RD strings that constitute a single sentence. Nomura (2008:25–29) states that an RD string displays an intonation pattern distinct from that for the mere juxtaposition of two separate strings: the RD part is uttered with the intonation contour following that of the preceding clause. All of our RD examples should thus be read with this intonation.

Now that the intonational facet of RDs has been clarified, we shall survey previous treatments of Japanese RDs in what follows.

Firstly, our incremental analysis looks similar to Kuno's (1978) functional analysis. Kuno argues that (2b) is ungrammatical due to information controversy between the preceding clause and the RD part. As shown in (4), the preceding clause invokes a polar question, while the RD part invokes a *wh*-question.

(4) *Kuno's (1978) functional analysis*
$\underbrace{\text{Ken-ga } \Delta \text{ tabe-ta-no,}}_{\text{polar question}} \quad \underbrace{\textbf{nani-o}\text{?}}_{\textit{wh}\text{-question}}$

At the time of hearing *nani-o*, the hearer has to modify the polar question reading into the *wh*-question reading. Kuno contends that this forced change of interpretation results in ungrammaticality.

In this account, however, it is not clear how (5) is treated.

(5) nani-o tabe-ta-no, **Ken-ga**?
Δ what-ACC eat-PAST-Q Ken-NOM
'What did Ken eat?'

The preceding clause invokes a *wh*-question, but how about the RD part *Ken-ga*? Kuno would need to stipulate that the RD part also invokes a *wh*-question, although the RD part does not contain any *wh*-phrase. Further, it is obscure what predictions could be drawn for the island data (section 5). Thus, whilst the insight of Kuno's analysis is shared with our account, its theorising is vague in some respects.

Turning to a more formal line of analysis, Takita (2011), Tanaka (2001), and Whitman (2000) address (2b). The heart of these analyses is "bi-clausal"; the pre-RD part and the RD part both form a clause, with the second clause being covert except for an RD item. This is illustrated with example (2b), based on Tanaka 2001.

(6) *Bi-clausal structure (Tanaka 2001)*
[Ken-ga Δ_i tabe-ta-no] [nani-o$_i$ ~~[Ken-ga t$_i$ tabe-ta-no]~~]

For Tanaka (2001), *nani-o* is scrambled within the second clause, and the rest is deleted. Given that the two clauses must be identical, the gap Δ must be occupied by an item that is identical to the RD part. In (2b), the gap is occupied by a *pro* and cannot be a *wh*-phrase. This structural inconsistency results in ungrammaticality.

For the bi-clausal approach, however, mixed *wh*-data such as (7)–(8) would be problematic.

(7) ?	Ken-ga	dokode	Δ	tabe-ta-no,	**nani-o**?
	Ken-NOM	where		eat-PAST-Q	what-ACC

'Where did Ken eat what?'

(8) ?	Ken-ga	Δ	nani-o	tabe-ta-no,	**dokode**?
	Ken-NOM		what-ACC	eat-PAST-Q	where

'Where did Ken eat what?'

These are grammatical, indicating that the clause-identity condition is satisfied. To account for them, one must stipulate that the gap is a covert *wh*-phrase in (7)–(8), but not in (2b). (Otherwise, (2b) would be wrongly predicted to be grammatical.)

In another account, Takano (2014:153) claims that a *wh*-phrase cannot be the RD part in terms of information structure. The RD part is considered to be a non-focal position. In Takano's theoretical implementation, an RD item is marked with [−F(ocus)], as exemplified in (9) based on (1b).

(9) *[−F(ocus)] assignment (Takano 2014)*

?Ken-ga	Δ tabe-ta-yo,	**sushi-o**$_{[-\mathrm{F(ocus)}]}$.	
Ken-NOM	eat-PAST-FP	sushi-ACC	

'Ken ate sushi.'

On the other hand, it is normally assumed that a *wh*-phrase conveys focal information. Thus, if the RD part is a *wh*-word such as *nani* in (2b), it cannot be marked with [−F(ocus)]. This is why a *wh*-phrase is not licensed as the RD part. (The core concept of this analysis, "information structure," is also a basis for the functional analysis presented in Takami 1995a,b.)

The mixed data in (7)–(8) are also a problem for this reasoning. Unlike (2b), (7)–(8) are grammatical, indicating that the RD part is occupied with non-focal information. It is then not clear in what sense *nani* in (7) is construed as non-focal information, though *nani* in (2b) is construed as focal information.

The data surveyed here, as well as other sets of data to be provided later, threaten previous syntactic studies (if not refute them). In this paper, we will seek another mode of analysis, from the perspective of how an interpretation is gradually accumulated, reflecting online parsing.

3 Dynamic Syntax

Dynamic Syntax (DS) specifies a set of procedures/constraints used to update a structured interpretation based on the dynamics of incremental parsing.[2] The notion "syntax" here refers to an abstract system that formalises the growth of interpretation, not a system that generates a structure inhabited by lexical items and their syntactic categories (Cann et al. 2005, Kempson et al. 2001, 2011).

As DS dispenses with syntactic structures, a string of words is directly mapped onto a semantic structure. For instance, as the string in (10) (re-

[2]This paper focusses on "comprehension," but DS models "production" with the same machinery (e.g., Howes 2012, Purver et al. 2014). See also Kahraman 2011, Kamide 2006, etc. for the experimental results suggesting that Japanese sentence processing is incremental.

peated from (1a)) is incrementally parsed, an interpretation of the string is gradually updated, which is formalised as the progressive growth of the semantic tree. The final output of this tree growth is given in (11).

(10) Ken-ga sushi-o tabe-ta-yo.
Ken-NOM sushi-ACC eat-PAST-FP
'Ken ate sushi.'

(11) Parsing the string (10) (ignoring tense)

$tabe'(sushi')(Ken') : t$
- $Ken' : e$
- $tabe'(sushi') : e \rightarrow t$
  - $sushi' : e$
  - $tabe' : e \rightarrow (e \rightarrow t)$

Note that (11) is a semantic (not syntactic) tree. Each node is decorated with a pair of (i) a semantic content such as *Ken′* and (ii) a semantic type such as *e* (i.e., "entity" type).

In DS, three kinds of tree state are distinguished: (i) an initial state, (ii) mid-states, and (ii) a final state. The initial state is defined as in (12). Any tree update thus starts with this tree state.

(12) AXIOM (= the initial state)

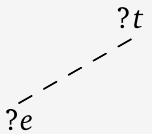
$?t$

$?t$ requires that this node will be decorated with a type-t content. In general, $?\alpha$ at a node forms a requirement that the node be decorated with α before a tree update finishes, where α may be a semantic content, a semantic type, etc. (see below).

The requirement $?t$ is satisfied once a whole string is successfully parsed, as in (11), which is in a final state. The mid-states between the initial state (12) and the final state (11) are derived by two types of action: "general" actions and "lexical" actions.

General action: DS defines non-lexically encoded actions, such as LOCAL *ADJUNCTION, an action to introduce a structurally-unfixed node. In the tree (13), the unfixed node (shown by a dashed line) may be a subject node, an object node, etc.[3]

(13) LOCAL *ADJUNCTION



The application of general actions is optional. That is, as long as the input condition to a general action is met, the parser may (but does not have to) apply it. For instance, the input condition to LOCAL *ADJUNCTION is that the present node be decorated with $?t$. This condition is met in the tree state (12), and the parser may apply LOCAL *ADJUNCTION, as shown in (13).

Lexical action: Every lexical item encodes a tree-update action. Ken encodes the action to decorate a $?e$-node with the pair of (i) the content Ken' and (ii) the type e, as in the left-hand tree of (14).

(14) Parsing *Ken* Parsing *Ken-ga*

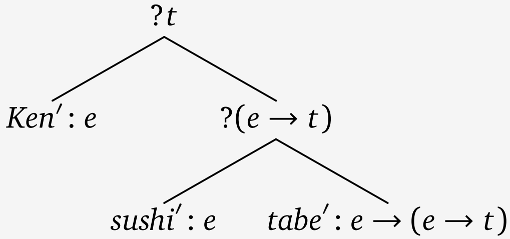
The nominative particle *-ga* encodes the action to resolve an unfixed node as a subject node, as in the right-hand tree of (14).

In this way, tree update proceeds through a combination of general and lexical actions. During the course of tree update, any information cannot be lost or modified, hence monotonicity.

For additional examples of general and lexical actions, consider the subsequent update of (14). After LOCAL *ADJUNCTION creates an unfixed node, it is decorated by the parse of *sushi* and is resolved as an object node by the parse of the accusative particle *-o*. The verb *tabe-* 'eat' then projects a predicate structure.

[3]As DS dispenses with syntactic representations, the terms like "subject node" and "object node" are used for the sake of convenience. These nodes are structurally defined; for instance, a subject node is a left-daughter of a root node in a propositional structure.

(15) Parsing *Ken-ga sushi-o tabe*



The parser finally performs functional application and type deduction (defined as the general action of Elimination), and the final state (11) is created.

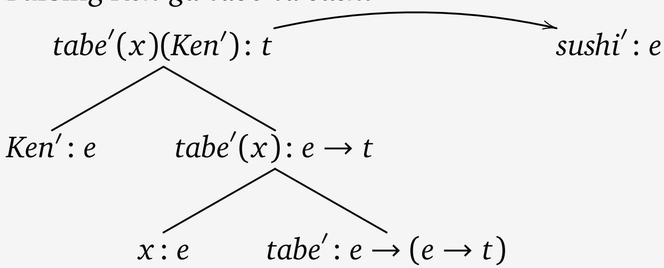
Finally, the LINK mechanism allows two trees to be paired. In (16), the parse of the relative clause *Ken-ga tabe-ta* constructs a tree, which is LINK-ed to a new node, to be decorated by the head noun *sushi*.

(16)

[[Ken-ga	tabe-ta]	sushi]-ga	oishikat-ta.
[[Ken-NOM	eat-PAST]	sushi]-NOM	delicious-PAST

‘The sushi which Ken ate was delicious.’

(17) Parsing *Ken-ga tabe-ta sushi*



In (17), the gap in the relative clause is simply notated as a variable x, and a LINK relation is expressed as a curved arrow.[4] The node for *sushi* will be identified as a subject node in a matrix structure by the parse of the nominative particle *-ga*. This matrix structure will then be fleshed out

[4]More formally, the content of the gap is notated in the “epsilon calculus” (Kempson & Kurosawa 2009). It is assumed in DS that predicates in Japanese project an open propositional structure where each argument slot is notated with a metavariable (Cann et al. 2005). In the case of the gap, a metavariable is saturated as a term with a maximally abstract predicate.

by the parse of *oishika-* ‘delicious’.

In short, DS is an abstract system that models progressive update of interpretation (represented as a semantic tree), reflecting the dynamics of time-linear parsing.

4 Incremental Account

Building upon and extending the DS framework, we shall now formalise our incremental analysis sketched in section 1. We first develop an analysis of RDs without wh-phrases (section 4.1). This will serve as a basis for explaining why the RD of *wh*-phrases is generally banned (section 4.2) but nonetheless why such RDs are permitted in certain syntactic environments (section 4.3).

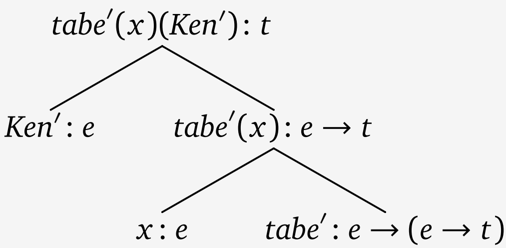
4.1 RDs without *Wh*-Phrases

Consider the RD string (18) (cf. (1b)), where the object NP *sushi* is postposed. (The accusative marker *-o* is optional, more on which see below.)

(18)	Ken-ga	Δ	tabe-ta-yo	**sushi(-o)**.
	Ken-NOM		eat-PAST-FP	sushi(-ACC)
	‘Ken ate sushi.’			

(18) is incrementally processed. If it is parsed up to the final particle *yo* (i.e., prior to the RD item *sushi*), the semantic tree (19) has been built up, where the gap is simply notated as a variable x.

(19) Parsing *Ken-ga tabe-ta-yo*

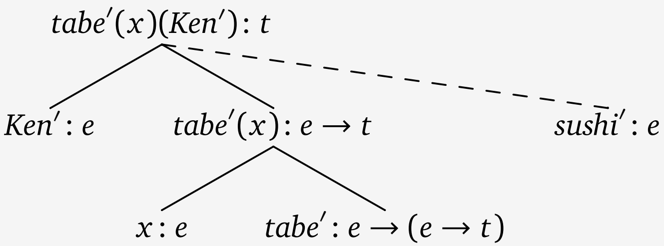


In order to parse the RD item *sushi*, the general action of LOCAL *ADJUNCTION needs to be run, but the action can apply only if the root node is decorated with $?t$ (Cann et al. 2005). This restriction models Japanese as verb-final. Still, on the assumption that RDs are colloquially abundant, we extend the formalism with (20).

(20) *Proposal 1.* In colloquial speech, the ?t-restriction on Local *Adjunction is relaxed.

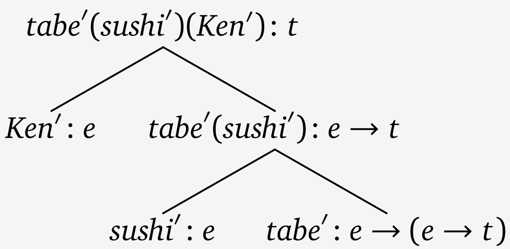
This proposal has the potential of capturing register variation. The idea is that some grammatical rules may be violated colloquially and that such violations (prescriptively seen as the wrong use of language) are a factor responsible for register variation. Once Local *Adjunction is allowed to apply in the environment (19), it creates an unfixed ?e-node, where the RD element *sushi* is parsable.

(21) Parsing *Ken-ga tabe-ta-yo, sushi*



In (18), the case-marking of *sushi* is optional. If *-o* is present, it resolves the node for *sushi* as an object node, updating x with the content $sushi'$. If *-o* is absent, the general action of Merge unifies the unfixed node with the already-fixed object node (Cann et al. 2005:chap. 2). After Elimination is run, the final state is as in (22).

(22) Parsing the RD string (18) (= final state)



In our analysis, the presence of a case particle triggers a lexical action to resolve an unfixed node, whereas the absence of it triggers a general action to the same effect. No matter which action applies, the identical structure emerges.

In sum, DS offers a uniform analysis of RDs with/without case-marking, where "uniform" means: though case-marking affects the way a tree is updated, the output is identical, ensuring that case-marking does not affect the truth-conditional content of RDs.[5]

4.2 RDs with *wh*-Phrases: Ungrammatical Cases

We now explicate why the RD of a *wh*-phrase is generally prohibited. Consider example (23).

(23) *Ken-ga △ tabe-ta-no, **nani-o**?
Ken-NOM eat-PAST-Q what-ACC
Intended: 'What did Ken eat?'

Interrogatives have not yet been seriously studied in DS. Kempson et al. (2001:chap. 5) assume that a *wh*-question is represented by a structure with a WH feature. In order to analyse the *wh*-licensing data of RDs, we shall advance this feature-based analysis with reference to Japanese interrogatives in what follows.

Japanese has a question marker *no* which licenses a string with a *wh*-phrase as a *wh*-question, as in (24), or a string without a *wh*-phrase as a polar question, as in (25).

(24) Ken-ga nani-o tabe-ta-no?
Ken-NOM what-ACC eat-PAST-Q
'What did Ken eat?'

(25) Ken-ga tabe-ta-no?
Ken-NOM eat-PAST-Q
'Did Ken eat that?'[6]

In line with Kempson et al. (2001:chap. 5), we maintain that a *wh*-question is modelled by a WH feature at the root node. In a similar vein, we assume that a polar question is modelled by a POL(ar) feature. We then propose

[5] Tanaka & Kizu (2007) and Takita (2014) hold that the case-marking of the RD part affects island sensitivity. Section 5 shows that this contrast in terms of island sensitivity follows from our unified analysis without stipulations.

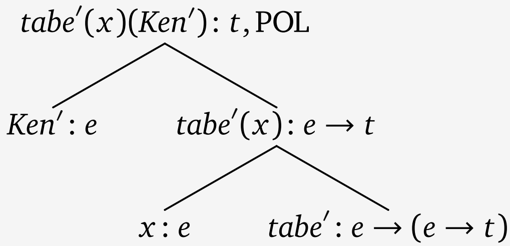
that (i) the parse of a *wh*-word posits the requirement ?WH at the root node, and that (ii) the parse of a question marker satisfies this requirement (that is, it deletes the requirement and posits a WH feature).[7] This idea is formulated as (26).

(26) *Proposal 2.* A *wh*-word in Japanese puts ?WH at the root. ?WH is licensed as WH by a question marker such as *no*. If ?WH is absent, a question marker puts POL at the root.

With this proposal, the ungrammaticality of (23) as well as the *wh*-licensing pattern in various types of RD string follow from the general mechanism of DS incremental, monotonic tree update.

The pre-RD clause in (23) does not contain a *wh*-phrase, and thus yields the tree where *no* has posited a POL feature. (Note that the parse of *no* does not create any new nodes but puts the feature POL at the root node.)

(27) Parsing *Ken-ga tabe-ta-no* in (23)

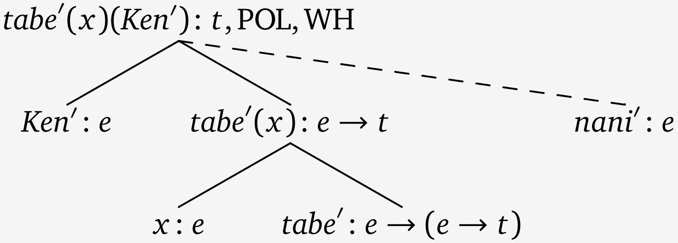


The tree contains a POL feature which indicates that the tree represents a polar question. In fact, this part of the string in (23) is identical to the string (25), which is interpreted as a polar question (but not as a *wh*-question).

The parse of (23), however, is not complete. What comes next in the string is the RD element *nani* 'what'. The parse of this *wh*-phrase adds ?WH to the root node of the tree (27), as illustrated in (28).

[7]The issue of question scope (Nishigauchi 2004) is disregarded. This would be dealt with in terms of the interaction between (i) the entry of a question marker and (ii) the general mechanism of "scope statement" (Cann et al. 2005:chap. 3).

(28) Parsing *Ken-ga tabe-ta-no, nani* in (23)



The features POL and WH indicate different types of question and cannot cooccur. As stated in section 2, a DS tree update is monotonic, disallowing any information to be lost during structure building. In particular, it prevents the feature POL from being deleted or modified. Thus, inconsistency of features necessarily arises, and the string (23) is deemed to be ungrammatical.

Note that our account also handles the non-RD example (29) and its scrambled analogue (30).

(29) Ken-ga nani-o tabe-ta-no?
Ken-NOM what-ACC eat-PAST-Q
'What did Ken eat?'

(30) Nani-o Ken-ga tabe-ta-no?
what-ACC Ken-NOM eat-PAST-Q
'What did Ken eat?'

In these examples, *nani-o* posits ?WH, and the question marker *no* licenses it as WH. (In DS, word order in Japanese is captured as the order in which LOCAL *ADJUNCTION applies for an incoming word (Cann et al. 2005:chap. 6). Thus, neither informational deletion nor structural destruction occurs in these examples.

We have explicated our account by extending the DS formalism. The key concept is incremental, monotonic structure growth. Thus, once a feature such as WH or POL is introduced, it can be neither deleted nor modified. Then, if incompatible features are detected, the structure becomes ill-formed and the string parsed becomes ungrammatical. The core of our analysis is summed up in table 1. The second column specifies a feature

ex.	pre-RD part	RD part	grammaticality
(18)	ϕ	ϕ	✓
(23)	{POL}	{POL, WH}	*
(29)–(30)	{WH}	n/a	✓

Table 1 Examples considered in sections 4.1 and 4.2

set *prior to* the parse of the RD part. The third column specifies a feature set *after* the parse of the RD part. The RD of a wh-phrase as illustrated in (23) is not possible due to the inconsistent features: WH and POL. An expectation, then, is that if one can avoid positing inconsistent features at a node, an RD string containing a *wh*-phrase could be grammatical. This expectation is borne out, as will be demonstrated in the next subsection.

4.3 RDs with *wh*-Phrases: Grammatical Cases

We turn to the grammatical cases of RDs with *wh*-phrases. These also fall into place in our incremental analysis.

First, consider the RD example (31).

(31) △ nani-o tabe-ta-no, **Ken-ga**?
what-ACC eat-PAST-Q Ken-NOM
'What did Ken eat?'

The parse of the preceding clause gives rise to the tree (32). As this clause contains *nani* 'what', the root node is annotated with the WH feature. (More precisely, the parse of *nani* first posits the requirement ?WH, and it is subsequently satisfied as WH by the parse of the question marker *no*.)

(32) Parsing *nani-o tabe-ta-no* in (31)

$tabe'(nani')(x): t, \mathrm{WH}$

$x : e$ $\quad$ $tabe'(nani'): e \rightarrow t$

$nani' : e$ $\quad$ $tabe' : e \rightarrow (e \rightarrow t)$

The RD element *Ken* is then parsed at an unfixed node. This parse incorporates *Ken′* into the tree (32) but does not add any information incompatible with the WH feature. This can be seen in the final state (33), where the unfixed node for *Ken* has been resolved as a subject node by the parse of the nominative particle *-ga*.

(33) Parsing *nani-o tabe-ta-no Ken-ga* in (31)

$$tabe'(nani')(Ken') : t, \mathrm{WH}$$

$$Ken' : e \qquad tabe'(nani') : e \rightarrow t$$

$$nani' : e \qquad tabe' : e \rightarrow (e \rightarrow t)$$

In (33), feature inconsistency is not detected, and the monotonicity of tree update is not violated either. Therefore, the RD string (31) is grammatical even though it contains the *wh*-word *nani*.

Second, if a preceding clause receives a *wh*-interrogative reading, a *wh*-phrase can constitute the RD part.

(34)	Ken-ga	nani-o	tabe-ta-no,	**nani-o**?
	Ken-NOM	what-ACC	eat-PAST-Q	what-ACC

‘What did Ken eat?’

In (34), *nani*, which is located at the gap position in the preceding clause, posits ?WH. The question marker *no* then licenses it as WH.

(35) Parsing *Ken-ga nani-o tabe-ta-no* in (34)

$$tabe'(nani')(Ken') : t, \mathrm{WH}$$

$$Ken' : e \qquad tabe'(nani') : e \rightarrow t$$

$$nani' : e \qquad tabe' : e \rightarrow (e \rightarrow t)$$

Subsequently, the parse of the RD item *nani* adds ?WH to the root, but it is harmless; the requirement ?WH is immediately satisfied by the feature

WH which has already been posited by the parse of *nani* in the preceding clause. Thus, (34) is acceptable.[8]

Third, consider the mixed *wh*-data, repeated here from (7) and (8), respectively.

(36) ? Ken-ga dokode Δ tabe-ta-no, **nani-o**?
Ken-NOM where eat-PAST-Q what-ACC
'Where did Ken eat what?'

(37) ? Ken-ga Δ nani-o tabe-ta-no, **dokode**?
Ken-NOM what-ACC eat-PAST-Q where
'Where did Ken eat what?'

In each example, the preceding clause comprises a *wh*-phrase, and it posits ?WH (to be licensed by *no*). Then, even if another *wh*-phrase is processed as the RD part, it does not alter the WH feature specification. This is because the type of *wh*-word (e.g., *what*, *where*) is not reflected in the feature specification.

Finally, (38) looks like a (putative) counterexample; it is acceptable though *nani* appears sentence-finally. (38), however, receives a "specificational" reading (Declerck 1988, Nishiyama 2003), as in the cleft string (39). (In (38)–(39), *no* is regarded as a nominaliser; *no* in Japanese is lexically ambiguous between a question particle and a nominaliser.)

[8] The standard DS machinery (Cann et al. 2005) generates strings such as (i), where *sushi-o* is duplicated.

(i) Ken-ga sushi-o sushi-o tabe-ta.
Ken-NOM sushi-ACC sushi-ACC eat-PAST
'Ken ate sushi.'

As for the first instance of *sushi-o*, *sushi* is parsed on a locally unfixed node, and this unfixed node is resolved as an object node by the parse of the accusative particle *o*-. Then, *sushi* in the second instance of *sushi-o* is also parsed on a locally unfixed node, and this unfixed node is resolved as an object node by the parse of *o*-. As the object node has already been created, this second resolution is structurally vacuous. Examples like (i) may be unacceptable prescriptively, but they would be acceptable colloquially, with the assumption that the speaker utters *sushi-o* as a repetition for discourse purposes (e.g., emphasis, clarification). We are grateful to an anonymous referee for bringing this issue to our attention.

ex.	pre-RD part	RD part	grammaticality
(31)	{WH}	{WH}	✓
(34)	{WH}	{WH, WH}	✓
(36)–(37)	{WH}	{WH, WH}	✓

Table 2 RD examples considered in section 4.3

(38) Ken-ga tabe-ta-no nani?
Ken-NOM eat-PAST-NMNS what
'What is it that Ken ate?'

(39) [Ken-ga tabe-ta-no]-wa nani?
[Ken-NOM eat-PAST-NMNS]-TOP what
'What is it that Ken ate?'

So, (38) is likely to be a *wa*-stripped cleft. A cleft with an *o*-marked focus is said to be degraded for many speakers (Hiraiwa & Ishihara 2012); in fact, if the accusative particle -*o* is attached to *nani*, both (38) and (39) are degraded. Thus, it seems (38) is not an RD but a cleft (see Seraku 2013 for a DS account of Japanese clefts).

In sum, as an RD string is parsed left to right, a tree is incrementally updated. The monotonic nature of DS tree update accounts for why RD strings with *wh*-phrases are sometimes (though not always) grammatical. The insight of the analysis is delineated in table 2. In each example, no incompatible features are present at a node. It is thus correctly predicted that these RD strings are all grammatical (modulo other grammatical principles and rules).

Let us close this subsection by pointing out a residual problem. Data such as (40) (repeated from (34)) are cited in Takita 2011 and Tanaka 2001. We further note that case-marking affects acceptability, as in (41). Our analysis predicts that the strings under (41) are all grammatical.

(40) Ken-ga nani-o tabe-ta-no, **nani-o**?
Ken-NOM what-ACC eat-PAST-Q what-ACC
'What did Ken eat?'

(41) a. ? Ken-ga nani-o tabe-ta-no, **nani**?
Ken-NOM what-ACC eat-PAST-Q what
b. ?? Ken-ga nani tabe-ta-no, **nani-o**?
Ken-NOM what eat-PAST-Q what-ACC
c. Ken-ga nani tabe-ta-no, **nani**?
Ken-NOM what eat-PAST-Q what

It seems a string is degraded when the form of an item at a theta position does not match that of an RD item. To take (41a) as an example, *nani-o* at a theta position is case-marked with *-o*, while *nani* at an RD position is not case-marked. We suspect that this formal difference may lower acceptability: when the speaker repeats part of a clause postverbally, its effect (e.g., emphasis) is not achieved well if the form is different. In fact, the same acceptability pattern obtains if *nani* in (41) is replaced with a non-*wh*-word like *sushi*. The upshot is that the strings in (41) are grammatical (especially, compared with (23)), and that they should not be ruled out by a grammar.

Our analysis is thus vindicated by a wide spectrum of RD data. Nevertheless, there are several topics that cannot be covered in the present paper. Japanese allows other types of RD element than NPs, such as AdvPs and APs. Furthermore, it also allows more than a single RD element (Abe 1999). These issues are handled in Seraku & Ohtani 2016.

5 Island Sensitivity of RDs

Section 4 unified case-marked and caseless RDs by arguing that they are mapped onto the identical structure (though the way a structure is built up differs depending on whether or not the RD part is case-marked). This unified analysis, though theoretically preferable, encounters the puzzle of how to explain away the data which have been taken to motivate a non-uniform analysis: island sensitivity of RDs. This section shows that our account accommodates such data without relinquishing uniformity of analysis.

5.1 Data and Previous Treatments

Tanaka & Kizu (2007) and Takita (2014) note that case-marked RDs are sensitive to island constraints while caseless RDs are not. In (42), the gap

Δ is found in the relative clause *Mari-ga age-ta*. What matters here is the Complex NP Constraint (Ross 1967).

(42) Ken-ga [[Mari-ga Δ age-ta] hito]-o sagashitei-ta-yo,
Ken-NOM [[Mari-NOM give-PAST] person-ACC looking.for-PAST-FP
ano-hon(*-o).
that-book(-ACC)
'Ken was looking for a person to whom Mari gave that book.'
(Takita 2014:139, modified)

If the RD part *ano-hon* 'that book' is case-marked, the string is sensitive to the island constraint, hence ungrammatical. By contrast, if *ano-hon* is caseless, it is not sensitive to the island constraint, hence grammatical. (See Takita 2014 for other types of island.)

Both Tanaka & Kizu (2007) and Takita (2014) tackle this island sensitivity pattern by positing radically distinct structures depending on whether an RD item is case-marked. For example, Tanaka & Kizu hypothesise the following structures:

(43) *Structure for case-marked RDs (Tanaka & Kizu 2007)*
Op_i [... $[_{\text{CP}}$ t_i $[_{\text{CP}}$ ... t_i ...]] ...] XP_i-case

(44) *Structure for caseless RDs (Tanaka & Kizu 2007)*
Op_i [... t_i $[_{\text{CP}}$ ... pro_i ...] ...] XP_i

In both structures, an RD item corresponds to XP and is co-indexed with the null Op(erator). In (43), Op moves from a theta position in an island to the sentence-initial part. In this movement, Op *crosses* an island, hence the island sensitivity of case-marked RDs. In (44), the theta position is inhabited by a *pro* co-indexed with Op. Op movement starts from the outside of an island; notice the position of the trace t_i. In this movement, Op does *not* cross an island, and this is why caseless RDs appear to not be island sensitive.

This distinct-structure approach looks reasonable, but there is a reservation. Nothing seems to prevent us from attaching a case particle to XP in (44). That is to say, it is not clear how a structure like (45) is banned.

(45) *Structure for caseless RDs (Tanaka & Kizu 2007)*
Op_i [… t_i [$_{\mathrm{CP}}$ … pro_i …] …] XP_i-case

Unless structure (45) is blocked, case-marked RDs are predicted to not be island sensitive, contrary to fact. The same problem arises for Takita (2014), who also posits distinct structures depending on the case-marking of an RD element.

Whilst there may be syntactic solutions to this problem, the next subsection shows that the problem does not arise in our account in the first place.

5.2 LINK-Based Analysis

According to our analysis of RDs in section 4, an RD item is parsed at an unfixed node introduced by Local *Adjunction. An unfixed node created by this action, however, must be resolved in a "local" structure, and so it cannot handle island data.[9]

Instead of an unfixed node, however, the parser could launch a LINK relation to parse an RD element. As LINK allows information passing across an island, the RD part *ano-hon* in (42) is parsable at the LINK-ed ?*e*-node, as shown in (46).

(46) Parsing (42) prior to the RD item *ano-hon*

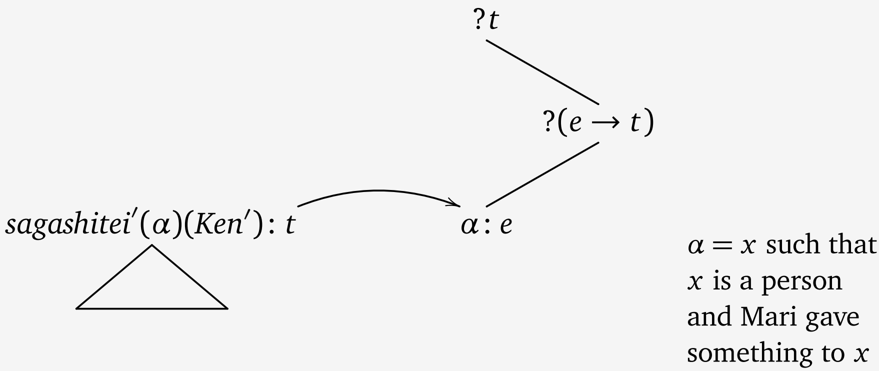
$sagashitei'(\alpha)(Ken') : t \longrightarrow ?e$

$\alpha = x$ such that x is a person and Mari gave something to x

If the accusative particle *-o* is absent, the term at the LINK-ed node (i.e., hon') is incorporated into the main tree (formalised as the general action of LINK Evaluation). Therefore, the caseless RD in (42) is grammatical. If *-o* is present, the current node will be fixed as an object node within a new tree (Seraku 2013), as shown in (47).

[9] In DS, each node position is defined in the "Logic of Finite Trees" (Blackburn & Meyer-Viol 1994). An unfixed node indicates that it may occupy any node position in a restricted domain. In the case of Local *Adjunction, an unfixed node must be resolved within a local propositional tree.

(47) Parsing (42) (with *-o* in the RD item *ano-hon-o*)



In (47), the emergent tree cannot be further built and the requirements $?t$ and $?(e \rightarrow t)$ are left outstanding. Thus, the case-marked RD in (42) is ungrammatical.

In DS, a LINK-analysis has been proposed for RDs in several languages: English (Cann et al. 2004), Greek (Chatzikyriakidis 2011, Gregoromichelaki 2013), and Mandarin (Wu 2005). These accounts themselves are motivated theoretically and empirically, but since a LINK-analysis is inconsonant with case markers (see the paragraph above for details), they are not applicable to Japanese case-marked RDs (unless stipulations are made). In our account, case-marked RDs are treated by dint of unfixed nodes (not LINK-ed nodes).

So, in our account, there are two means of parsing an RD string: unfixed-node-based and LINK-based. This conforms to the general DS stance that a string-structure pair is not predetermined. Given the two parse routes and the two types of RD, there are logically four pairings, as summarised in table 3. (Note that the "Result" in this table specifies whether a parse fails for the kinds of RD string where the gap is found inside a relative clause in a complex NP.) Although the LINK-based parse alone has so far been examined for (42), the unfixed-node-based parse does not alter the conclusion of our discussion, as will be argued in what follows.

Let us first consider case-marked RDs, namely, (i)/(ii) in table 3. If the case-marked RD item *nani-o* in (42) is parsed at an unfixed node, the parse fails (see (i)). This is because, as mentioned at the outset of the present subsection, an unfixed node introduced by Local *Adjunction

	Type of RD	Type of Parse	Result
(i)	case-marked	unfixed-node	parse fails
(ii)	case-marked	LINK	parse fails
(iii)	caseless	unfixed-node	parse fails
(iv)	caseless	LINK	parse succeeds

Table 3 Type of RD and Type of Parse

must be resolved within a local structure. Further, the LINK-based parse also fails because the LINK-ed node is identified as an object node in a new structure by the parse of *-o*, but this structure cannot be further updated, as illustrated in (47) (see (ii)). Therefore, our account correctly predicts the island sensitivity of case-marked RDs.

Let us turn to caseless RDs, namely (iii)/(iv) in table 3. If the caseless RD element *nani* in (42) is parsed at an unfixed node, the parse fails (due to the reason in the previous paragraph; see (iii)). This result differs from the one based on a LINK-based parse (see (iv)). But this is not problematic; in DS, a string is grammatical if there exists a successful parse of the string. For the caseless RD in (42), there is indeed a successful LINK-based parse, namely, (iv), and so the string is grammatical. Hence, the island insensitivity of caseless RDs also follows from our account.

In a nutshell, DS enables us to integrate case-marked and caseless RDs without failing to account for their discrepancy in terms of island sensitivity. Moreover, our analysis avoids the potential problem of previous works mentioned in section 5.1.

In closing, it should not go unnoticed that the present account is applicable to other sets of data beyond RDs. Fukaya (2007) points out the same island sensitivity pattern as (42) for clefts, stripping, and sluicing (see also Hoji 1990). In DS, Seraku (2013) deals with them in virtue of LINK, which is fully consonant with the analysis presented in this section. Thus, our account of RDs is generalisable to these focus/ellipsis constructions, too.

6 Conclusion

The distribution of *wh*-phrases in Japanese RD constructions follows from the incremental, monotonic growth of interpretation. The main results of this paper are condensed into the following points:

- We observe that there are instances where a *wh*-phrase is licensed as the RD part. These data challenge past analyses, making a case for an incremental account.
- Our incremental account integrates case-marked and caseless RDs, and correctly predicts the *wh*-licensing pattern.
- The account is further confirmed by other sets of data such as island sensitivity of RDs.
- The formalisation of the analysis leads to advances in the DS framework.

As general implications, putting a grammar on an incremental footing develops a "realistic" grammar (Sag & Wasow 2011), and it makes claims experimentally testable in terms of incremental parsing (Kiaer 2014). A specific benefit of adopting DS in this light is that there is a growing body of DS research on dialogue (Purver et al. 2014). Since RDs appear in casual speech, and casual register is typically manifested in dialogue, DS opens up the avenue of addressing spontaneous RD data. Seraku & Ohtani (2016) present a preliminary analysis of naturally-occurring RDs in the conversational part of Japanese novels.

Another future prospect is to test the claims made in this paper against cross-linguistic data. In the context of DS, RD data from languages like English, Greek, and Mandarin have been considered (recall the references in section 5). It is left for future research to examine cross-linguistic parallelisms and differences in the syntax of RDs in terms of incremental, monotonic growth of interpretation.

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The Existential Problem of Scalar Implicatures and Anaphora Across Alternatives

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Abstract It is argued that sentences of the form "$\exists x \ldots \sigma \ldots$," which contain both an existential quantifier $\exists x$ and a scalar item σ like *some*, *most*, etc. pose a challenge for standard views of scalar implicature computation that make use of alternative sentences. Specifically, it is observed that the predicted scalar implicature that $\neg(\exists x \ldots \sigma^{+} \ldots)$ for a stronger scalar item σ^{+} is systematically unavailable. In order to solve this problem, it is proposed that the existential quantifier contained in the alternative sentence behaves as an anaphoric term. This idea is formalized in File Change Semantics augmented with the exhaustivity operator exh. It is furthermore observed that there are two types of existential quantifiers in the modal domain in this respect: While the behavior of epistemic modals in alternative sentences is similar to that of indefinite DPs, root modals always behave as existential quantifiers, giving rise to scalar implicatures that $\neg(\Diamond \ldots \sigma^{+} \ldots)$. This difference is captured in File Change Semantics by assuming that indefinite DPs and epistemic possibility modals denote variables, while root possibility modals always perform random assignment.

Keywords scalar implicature · alternatives · anaphora · Dynamic Semantics · File Change Semantics

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1 Introduction

Sentences containing so-called scalar items like *some* and *most* typically give rise to scalar implicatures (SIs), as illustrated by (1).

(1) John read some/most of the books.
$\rightsquigarrow$ ¬(John read all of the books)

It is widely held that SI computation makes reference to alternative sentences.[1] For the sake of concreteness, I will adopt here the "grammatical view" of SI computation (Chierchia 2006, Chierchia et al. 2012, Fox 2007). It should be stressed, however, that the same problem arises in all views of SI computation that resort to alternative sentences.

According to the grammatical view of SIs, SIs arise via a phonologically silent operator exh, which is often defined as follows.

(2) $[\![\mathsf{exh}(S)]\!]^w = [\![S]\!]^w \wedge \forall S' \in \mathrm{Alt}(S)((S \nrightarrow S') \rightarrow \neg[\![S']\!]^w)$

In words, exh strengthens the meaning of the sentence S with the negation of alternatives S' that are not entailed by S. For instance, for (1), exh negates the alternative sentence in (3), which it does not entail.

(3) John read all of the books.

This accounts for the intuitively available SI that John did not read all of the books.

A crucial part of this theory of SIs is the theory of alternatives. In the above example, the SI in question is only explained under the assumption that the sentence in (3) counts as an alternative to (2). It is, however, beyond the scope of the present paper to thoroughly solve the vexing issue of how exactly alternatives are constructed. Here, we simply assume with Horn (1972) that alternatives are constructed by replacing scalar items with their lexically specified alternatives called "scale-mates" (e.g. *some*, *most*, and *all* are scale-mates).[2] This theoretical choice, however, is only tentative, and the assumptions I will make about alternatives will not rely crucially on lexically specified scale-mates.

[1]This of course does not mean that there are no theories without alternatives. See Van Rooij & Schulz 2004, 2006, and Van Rooij 2014, for example. The problem I will discuss in this paper does not arise in these theories, but detailed comparisons between these theories and alternative-based theories are beyond the scope of the present paper.

[2]See Katzir 2007 and Fox & Katzir 2011 for problems of this view and an alternative view, but see Breheny et al. 2016 and references therein for potential problems for their theory.

2 The Existential Problem

A problem of the standard view of SIs arises when the sentence has the following schematic form:[3]

(4) $\exists x \ldots$ some/most …

If we construct an alternative by replacing the scalar item *some/most* with *all*, it will look like (5).

(5) $\exists x \ldots$ all …

Since this alternative is not entailed by (5), exh negates it, deriving the SI (6).

(6) $\neg(\exists x \ldots \text{all} \ldots)$

The problem, which I call the *existential problem* here, is that this SI is too strong. Rather, the SI that is actually available seems to be about the same individual that $\exists x$ in the asserted sentence introduces. Thus, the sentence with the SI seems to mean (7a), rather than (7b).

(7) a. $\exists x(\ldots \text{some/most} \ldots \wedge \neg(\ldots \text{all} \ldots))$
b. $\exists x(\ldots \text{some/most} \ldots) \wedge \neg\exists x(\ldots \text{all} \ldots)$

Here is an example illustrating this problem. As *some* allows an exceptional wide scope reading, which is not of our interest here, we will use *most* in the examples below.

(8) There are one or more students who read most of the books.

The problematic existential quantifier $\exists$ comes from *one or more students* (which is assumed to have no relevant SI of its own). The alternative sentence will look like (9).

(9) There are one or more students who read all of the books.

[3] Geurts (2008, 2009) independently notices the same problem, and makes suggestions that are closely related to what is proposed here, but he does not present a concrete implementation or discuss the differences among quantifiers in different domains.

By negating this, we obtain the SI that no student read all of the books. Intuitively, however, this is not the SI of (9). Rather, one tends to infer that the students who read most of the books did not read all of the books.

The same problem arises with other forms of $\exists$, as in (10).

(10) a. There is a student who read most of the books.
b. There are students who read most of the books.
c. There is at least one student who read most of the books.

These seem to mean (7a), rather than (7b).[4]

At this point one might wonder if this is really a problem, especially given that under the approach to SIs that postulates exh, (8) is predicted to have two possible SIs. One is what we have just derived by applying exh to the entire sentence, but there is also another possibility where exh takes scope within the relative clause. Since this reading corresponds to (7a), one might think that it is fine to also derive the other reading (7b), which is stronger, as a possible interpretation. Contrary to this, I argue that the reading predicted with wide scope exh in fact is absent and needs to be blocked. I make this point concrete by using two tests.

2.1 Hurford Disjunction Test

Our first test is the “Hurford Disjunction Test” (HDT).[5] It is known that disjunction is infelicitous if one of the disjuncts entails the other, as in (11) (Hurford 1974, Chierchia et al. 2012, Singh 2008).

(11) #Either John lives in London or he lives in the UK.

Interestingly, scalar items are seemingly exempt from this constraint, as illustrated by (12).

[4] However, one needs to be cautious about other pragmatic inferences than the SI triggered by the scalar item in question, which might lead one to conclude (7b), at least in certain contexts. For instance, upon asked if they have good students in their class this year, a professor could say (10a). This utterance typically triggers an inference that the student in question is the best student they have, or perhaps the only student that is worth mentioning in this context, from which one could conclude that the other students didn’t do better, so none of the students read all of the books. Arguably, this is due to other pragmatic considerations than SIs triggered by scalar items *per se*.

[5] I thank Jacopo Romoli (p.c.) for suggesting this to me.

(12) Either John read some of the books or he read all of them.

As suggested by Chierchia et al. (2012), one way to understand this state of affairs is that the first disjunct of (12) can have an SI within the disjunct it is contained in, which breaks the entailment to the other disjunct and makes the disjunction acceptable. In fact, the following sentence is synonymous with (12) and as acceptable.

(13) Either John read some but not all of the books or he read all of them.

This can be used as a test for potential SIs.[6] The logic is that if a sentence S can have $\neg S'$ as an SI and mean $(S \wedge \neg S')$, then a disjunction of the form 'Either S or S'' should be felicitous. If the disjunction turns out to be infelicitous, it suggests that $\neg S'$ is unavailable as a potential SI of S.

Let us apply this test to one of the examples we are after, (10b) (the same point can be made with the other examples mentioned above). The relevant sentence will look like (14).

(14) ??Either there are students who read most of the books, or there are ones who read most but not all and ones who read all.

Notice, importantly, that the other potential reading that there are students who read most but not all of the books doesn't not break the entailment here, as the same thing is asserted in the second disjunct. If the first disjunct here could mean (7b), there wouldn't be an entailment from the first disjunct to the second. Thus, the infelicity indicates that the SI that no student read all of the books is unavailable.

One important obstacle here, however, is that sentences like (14) are a mouthful and might not be easy for native speakers to judge, as the difficulty associated with the length of the sentence might make it sound already less than perfect. Nevertheless, the contrast with (15) is suggestive, which does have the inference (7b) as an entailment due to *only*.

[6] The validity of this test is not theoretically uncontroversial and should be independently defended. However, I do not think this paper is the right place to do so, and leave it for future work.

(15) Either there are only students who read most$_F$ of the books, or there are ones who read most but not all and ones who read all.

It seems that (14) is comparatively worse than (15), suggesting that the reading (7b) is unavailable.

The difference between (14) and (15) also indicates an interesting difference between exh and *only*, which are often said to have very similar semantic functions, if not completely identical (Groenendijk & Stokhof 1984, Fox & Hackl 2006, Chierchia et al. 2012). The above contrast indicates that *only* does negate the stronger alternative and give rise to the reading (7b), while exh does not seem to do the same.

2.2 Question-Answer Pairs

Another test we could use to make the same point is question-answer pairs. As illustrated by (16), SIs can be used to provide justifications for negative answers to polar questions.

(16) Q: Did John read all of these books?
A: He read some of them, so no.

(16A) has an SI that John did not read all of the relevant books, which justifies the negative answer to the question.

The idea here is to set up a pragmatic context that requires the presence of the target SI. If it is available at all, the sentence is expected to be felicitous.

Let us apply this test to the sentence under consideration. Here, too, it is instructive to compare (17A) with the version of the sentence with *only*, as in (17A′).

(17) Q: Did any of your students read all of the books?
A: ??There are ones who read most of them, so no.
A′: There are only ones who read most$_F$ of them, so no.

As indicated by the question marks, (17A) does not seem to be a reasonable justification for the negative answer, suggesting that it cannot have the SI that there is no one who read all of the books. On the other hand, (17A′), which does have this inference as an entailment, can successfully justify the negative answer.

3 Alternatives in File Change Semantics

The existential problem pointed out in the previous section is a general overgeneration problem for alternative-based theories of SI computation. I now offer a solution whose underlying idea can be implemented in most, possibly all, of these theories, although I will stick to the framework with exh here for expository purposes. In particular, it should be pointed out that according to the idea proposed here, wide scope exh results in the same reading as narrow scope exh for the problematic sentences, which means that it does not rely on the embeddability of the SI computation mechanism (which is unavailable under some theories).

The main ideas are the following: we do not observe the predicted SI in sentences of the form $\exists x(\ldots$ some/most $\ldots)$, because there is an anaphoric term in the alternative instead of the existential quantifier.[7] Thus, the only reading we can derive looks like (18a), rather than (18b). In these representations, the second conjunct is meant to be the SI, and x in the second conjunct of (18a) is dynamically bound by $\exists x$.

(18) a. $\exists x(x$ read most of the books$) \wedge \neg(x$ read all of the books$))$
b. $\exists x(x$ read most of the books$) \wedge$
$\neg\exists x(x$ read all of the books$)$

3.1 File Change Semantics

To flesh out this idea more concretely, I adopt File Change Semantics (Heim 1982). A file F is a set of assignments, which are partial functions from variables $\mathcal{V}$ to objects $\mathcal{O}$ in the model. I assume that the assignments in a file have the same domain, and write $\mathrm{dom}(F)$ for the common domain of the assignments in F.

Variables carry two roles in this system. If a variable x is an "old variable" at F (i.e., $x \in \mathrm{dom}(F)$), it functions as an anaphor, while if it is a "new variable" at F (i.e., $x \notin \mathrm{dom}(F)$), it effectively acts as an existential quantifier by triggering *random assignment*. This is ensured by the rule for updating the file with simple sentences. $\mathcal{I}$ here is the interpretation

[7] See Bumford 2015 and Elliott & Sudo 2016 for related ideas.

function assigning the usual extensions to constants.

$$F[P^1(x)] := \begin{cases} \{ g \in F \mid g(x) \in \mathscr{I}(P^1) \} & \text{if } x \in \mathrm{dom}(F) \\ \{ g' \mid \exists g \in F(g[x]g' \wedge g'(x) \in \mathscr{I}(P^1)) \} & \text{if } x \notin \mathrm{dom}(F) \end{cases}$$

Here, $g[x]g'$ is a *random assignment* of a value to the variable x:

$$g[x]g' \text{iff } g \text{ and } g' \text{ differ at most in that } x \notin \mathrm{dom}(g) \text{ and } x \in \mathrm{dom}(g')$$

More generally, for n-place predicates:

$$F[P^n(x_1, \ldots, x_n)] := \left\{ g' \,\middle|\, \exists g \in F \left(\begin{array}{l} g[x_{i_1}]g' \wedge \ldots g[x_{i_m}]g' \\ \wedge \langle g'(x_1), \ldots, g'(x_n) \rangle \in \mathscr{I}(P^n) \end{array} \right) \right\}$$
$$\text{for each } x_{i_j} \text{ such that } x_{i_j} \notin \mathrm{dom}(F)$$

Both indefinites and pronouns introduce variables but indefinites are associated with a felicity condition requiring that they introduce a new variable, which is known as the "Novelty Condition." Crucially, this condition is understood to be a condition on speech acts, rather than a presupposition (cf. Heim 1991, Elliott & Sudo 2016). This assumption will become crucial when we compute alternatives.

The connectives are as in standard dynamic systems.

$$F[\phi \wedge \psi] := F[\phi][\psi]$$
$$F[\neg\phi] := \{ g \in F \mid \neg\exists g' \in F[\phi](g \leq g') \}$$

Here $g \leq g'$ iff for all $x \in \mathrm{dom}(g)$, $g(x) = g'(x)$.

As the scalar items in the examples in question are generalized quantifiers, I postulate dynamic selective generalized quantifiers (van Eijck & de Vries 1992, Kanazawa 1993, 1994, Chierchia 1995). For the purposes of the present paper, this is only for the sake of completeness, and the particular way of implementing dynamic generalized quantifiers here is largely inconsequential. To keep the discussion as simple as possible, I assume that generalized quantifiers are not externally dynamic, meaning they do not introduce new discourse referents (see van den Berg 1996, Nouwen 2003, 2007, Brasoveanu 2007, 2010a,b for externally dynamic generalized quantifiers).

Here are the details. Determiners are assumed to be associated with variables (indicated by superscripts), which are assumed to be subject to the Novelty Condition on a par with indefinites. For example, all has the following meaning. Here $g[x/o]$ is that assignment that differs from g at most in that $g[x/o](x) = o$.

(19) $$F[\mathsf{all}^x(\phi)(\psi)] := \left\{ g \in F \;\middle|\; \begin{array}{l} \{o \in \mathcal{O} \mid \{g[x/o]\}[\phi] \neq \emptyset\} \\ \subseteq \{o \in \mathcal{O} \mid \{g[x/o]\}[\phi][\psi] \neq \emptyset\} \end{array} \right\}$$

More generally, the interpretation of a determiner Q in the present system can be defined in terms of its classical counterpart $\mathbb{Q}$ of type $((et)((et)t))$ as follows:

(20) $$F[\mathsf{Q}^x(\phi)(\psi)] = \left\{ g \in F \;\middle|\; \begin{array}{l} \mathbb{Q}(\{o \in \mathcal{O} \mid \{g[x/o]\}[\phi] \neq \emptyset\}) \\ (\{o \in \mathcal{O} \mid \{g[x/o]\}[\phi][\psi] \neq \emptyset\}) \end{array} \right\}$$

The idea here is that the dynamic generalized quantifier Q collects the objects that make its restrictor ϕ true (the "maxset") and the objects that make both its restrictor ϕ and nuclear scope ψ true (the "refset"), and applies the classical generalized quantifier $\mathbb{Q}$ to these two sets. The fact that the refset refers both to the restrictor ϕ and nuclear scope ψ. See the works cited above for more on this.

3.2 Anaphora in Alternatives

Coming back to SIs, I propose that exh dynamically conjoins S and its negated alternatives. If the only relevant alternative of S is S', then we have:

$$F[\mathsf{exh}(S)] = F[S \wedge \neg S'] = F[S][\neg S']$$

More generally:

$$F[\mathsf{exh}(S)] := \left\{ g \in F[S] \;\middle|\; \forall S' \in \mathrm{Alt}(S) \left(\begin{array}{l} (F[S][S'] \subset F[S]) \\ \rightarrow g \in F[S][\neg S'] \end{array} \right) \right\}$$

That is, when there are multiple alternatives to S that could have strengthened S at F, that is, $F[S][S'] \subset F[S]$, then their SIs are computed in parallel.[8]

[8]Alternatively, the alternatives could be ordered and used to perform sequential updates, but I don't see any empirical reasons to favor or disfavor this possibility. I leave this as a theoretical choice.

To see how this works concretely, let us take the sentence (8) with the indexing as in (21a). The alternative sentence looks like (21b).

(21) a. There is one or more^x students who read most^y of the books.
b. There is one or more^x students who read all^z of the books.

It is crucial that the same variable x is used on *one or more* in (21a) and (21b), which is taken to be an indefinite determiner here, while the variables on the scalar items are distinct. I assume that this is ensured by how alternatives are constructed syntactically. That is, from the sentence (21a), the alternative (21b) is constructed by keeping everything, including the indices constant, except for the scalar item and the index on it.[9]

The sentences in (21a) and (21b) (without exh) are translated as (22a) and (22b), respectively.

(22) a. $\mathsf{student}(x) \wedge \mathsf{most}^y(\mathsf{book}(y))(\mathsf{read}(x,y))$
b. $\mathsf{student}(x) \wedge \mathsf{all}^z(\mathsf{book}(z))(\mathsf{read}(x,z))$

When exh is applied to (22a), the negation of the alternative (22b) is processed after (22a). Then, the variable x in it acts as an anaphoric term, because x is an old variable at $F[\,(21a)\,]$ (whenever $F[\,(21a)\,] \neq \emptyset$), although it is new at F. Notice here that the Novelty Condition (qua condition on speech acts) is not violated, because x is novel at F. The resulting file, then, is the following:

$$F[\,(22a)\,][\,\neg(22b)\,]$$

$$= \left\{ g' \;\middle|\; \exists g \in F \left(\begin{array}{l} g[x]g' \wedge g'(x) \in \mathscr{I}(\mathsf{student}) \\ \wedge\, \mathbb{MOST}(\{\, o \in \mathscr{O} \mid o \in \mathscr{I}(\mathsf{book})\,\}) \\ \quad (\{\, o \in \mathscr{O} \mid o \in \mathscr{I}(\mathsf{book}) \wedge \langle g'(x), o\rangle \in \mathscr{I}(\mathsf{read})\,\}) \\ \wedge\, \neg\mathbb{ALL}(\{\, o \in \mathscr{O} \mid o \in \mathscr{I}(\mathsf{book})\,\}) \\ \quad (\{\, o \in \mathscr{O} \mid o \in \mathscr{I}(\mathsf{book}) \wedge \langle g'(x), o\rangle \in \mathscr{I}(\mathsf{read})\,\}) \end{array} \right) \right\}$$

This amounts to the following reading: there is a student x who read at

[9]Note that this does not hinge on the theory of alternatives we are tentatively adopting here. Rather, it is an additional constraint that I am unable to derive from independent principles. I believe other theories of alternatives similarly do not necessarily predict this constraint. In fact, the structural theory of alternatives (Katzir 2007, Fox & Katzir 2011) might allow alternatives to have different indices and overgenerate here.

least most of the books, and it's not the case that *the same student x* read all of the books). Importantly, in the present account this is the only possible reading of the sentence, as the same SI is predicted if exh applies within the relative clause. Thus, the problematic SI cannot be generated here, and the existential problem does not arise.

4 Modals

So far so good. Interestingly, however, not all existential quantifiers give rise to the existential problem. Specifically, we observe that among existential quantifiers in the modal domain, that is, possibility modals, there are ones that behave differently from indefinite DPs. That is, sentences of the form $\Diamond(\ldots \text{some/most} \ldots)$ where $\Diamond$ is a root possibility modal do give rise to SIs such that $\neg\Diamond(\ldots \text{all} \ldots)$ holds. To see this more concretely, consider (23), where the relevant existential modal is the deontic possibility modal *allowed*.[10]

(23) John is allowed to read most of the books.
$\rightsquigarrow$ ¬(John is allowed to read all of the books)

One can infer from this sentence that John is not allowed to read all of the books. A HDT confirms this observation.

(24) a. Either John is allowed to read most of the books, or he can choose whether to read most of them or all of them.
b. Either John is only allowed to read most$_F$ of the books, or he can choose whether to read most of them or all of them.

Both of these sentences seem to be acceptable. Similarly, the following question-answer pair points to the same conclusion:

(25) A: Is John allowed to read all of these books?
B: He's allowed to read most of them, so no.
B′: He's only allowed to read most$_F$ of them, so no.

Other root possibility modals also give rise to SIs that $\neg\Diamond(\ldots \text{all} \ldots)$, for

[10] (23) has more SIs, which is due to the fact that *allowed* is also a scalar item. We will not discuss these SIs to simplify the discussion. See Fox 2007, Chemla 2009 and Romoli 2012.

example, other deontic possibility modals, as in (26), and ability modals, as in (27). As above, we are only interested in the narrow scope reading of the scalar item.

(26) a. You may eat most of the cookies.
$\rightsquigarrow$ ¬(You may eat all of the cookies)
b. You can keep most of this money.
$\rightsquigarrow$ ¬(You can keep all of this money)

(27) a. I can read most of these papers by tomorrow.
$\rightsquigarrow$ ¬(I can read all of these papers by tomorrow)
b. John is able to finish some of the work.
$\rightsquigarrow$ ¬(John is able to finish all of the work)

It is furthermore observed that there is variation among modals. Specifically, epistemic possibility modals differ from root possibility modals in this respect, and pattern with indefinite DPs. For example, the sentences in (28) do not seem to have the SI $\neg\Diamond(\ldots \text{all} \ldots)$, that is, they do not have SIs to the effect that the speaker considers it impossible that John read all of these books. Rather, the intuitively available reading is one where the SI seemingly takes scope below the modal.

(28) a. John might have read most of these books.
b. It is possible that John read most of these books.

This is confirmed with a HDT as in (29), and a question-answer pair test as in (30).[11]

(29) #Either John might have read most of these books, or all we know is that he read at least most, possibly all of them.

(30) Q: Do you think it's possible that John read all of the books?
A: #He might have read most of them, so no.

To summarize the observations, indefinite DPs and epistemic possibility modals do not give rise to SIs that involve negated existential quantifiers,

[11]Unfortunately, the corresponding sentences with overt *only* cannot be constructed, due to restrictions on the scope of *only* relative to epistemic modals. Yet, the judgments seem to be reasonably robust.

while root possibility modals do. In order to account for this difference, I claim that indefinite DPs and epistemic possibility modals denote variables, while root possibility modals are always interpreted as existential quantifiers, even in alternatives. I will demonstrate below that File Change Semantics offers a way to model this difference.

4.1 Epistemic Modals

Let us first tackle epistemic possibility modals, which work like indefinite DPs with respect to the existential problem of SIs.

It is known that modals have anaphoric properties, just like quantificational DPs. Anaphora in the modal domain is often discussed under the rubric of *modal subordination* (Roberts 1987, Geurts 1999, Stone 1999, Brasoveanu 2007, 2010a,b, Sudo 2014).[12] The phenomenon of modal subordination itself is not of particular interest here, but to illustrate, consider (31).

(31) John might come. John would bring a bottle of sake with him.

The meaning of the second sentence of (31) depends on *might* in the first sentence: *might* introduces the possibility that John will come, and the second sentence elaborates on this possibility by saying that if he comes he will bring a bottle of sake with him.

There are several theories of modal subordination in the literature, but I adopt here the idea of Stone (1999) and Brasoveanu (2010a) and postulate variables over sets of possible worlds (see also Sudo 2014). The theoretical choice here is largely arbitrary, however, and as far as I can see, nothing in the idea below crucially relies on this theory of modal subordination. That is, the only crucial part of the idea is that *might* is an indefinite in the modal domain.[13]

Let us see a concrete example. The first conjunct of (31), for example, can be given the following meaning, where ω is a variable over sets of possible worlds, functioning as the modal base for the epistemic modal.

[12]The term *modal subordination* is often used to refer also to pronominal anaphora mediated by modal anaphora, for example, *John might bring a bottle of sake with him. But he wouldn't share it with us*. Such complex cases are not of our concern here.

[13]This, however, means that we could not use the theory of epistemic modals as tests due to Veltman (1996).

We assume *John* is a rigid designator denoting j, and assignments are functions from variables over objects $\mathscr{V}_o$ and variables over sets of possible worlds $\mathscr{V}_w$ to objects $\mathscr{O}$ and possible worlds $\mathscr{W}$. In addition, $\mathscr{I}$ is parametrized to a possible world. Dox_s is the set of doxastic alternatives for the speaker. As with indefinite DPs, I assume that *might* is subject to the Novelty Condition, requiring at the speech act level that it introduce a new discourse referent.

(32) $$F[\mathsf{might}^{\omega}(\mathsf{come}(j))]$$
$$= \begin{cases} \{\, g \in F \mid \exists w \in g(\omega)(j \in \mathscr{I}_w(\mathsf{come}))\,\} & \text{if } \omega \in \mathrm{dom}(F) \\ \left\{ g' \;\middle|\; \begin{array}{l} \exists g \in F(g[\omega]g' \wedge g'(\omega) \subseteq \mathsf{Dox}_s \\ \wedge \forall w \in g(\omega)(j \in \mathscr{I}_w(\mathsf{come}))) \end{array} \right\} & \text{if } \omega \notin \mathrm{dom}(F) \end{cases}$$

In order for this analysis to be complete, some presuppositions need to be added. For instance, whenever old, ω should be a set of epistemic possibilities, rather than any set of possible worlds. One could also state the meaning of mood as a presupposition, for example, indicative mood presupposes that the actual world might be in ω. To avoid unnecessary clutter, I will omit these presuppositions here.

The important aspect of this analysis is that *might* introduces a new set of epistemic possibilities, which later sentences can anaphorically refer back to. In the above example, *would* refers to the possibilities that John will come and discard all the assignments but g such that in all $w \in g(\omega)$ John will bring a bottle of sake in w.

(33) $$F[\mathsf{would}_{\omega}(\mathsf{sake}(x) \wedge \mathsf{bring}(j,x))]$$
$$= \{\, g \in F \mid \forall w \in g(\omega)(g(x) \in \mathscr{I}_w(\mathsf{sake}) \wedge \langle j, g(x)\rangle \in \mathscr{I}_w(\mathsf{bring}))\,\}$$

Let us now combine this analysis of epistemic modals and our analysis of SIs developed in the previous section. Sentences like (28) above are, then, predicted to lack SIs of the form (7b), on the assumption that the variable associated with the epistemic possibility modal stays the same in the alternative. This is shown more concretely in (34).

(34) $$F[\mathsf{exh}(\mathsf{might}^{\omega}(\mathsf{most}^{x}(\mathsf{book}(x))(\mathsf{read}(x,j)))))]$$
$$= F[\mathsf{might}^{\omega}(\mathsf{most}^{x}(\mathsf{book}(x))(\mathsf{read}(x,j)))]$$
$$[\neg(\mathsf{might}^{\omega}(\mathsf{all}^{y}(\mathsf{books})(\lambda x.\mathsf{read}(j)(x))))]$$

As in the case of indefinite DPs, it is crucial that *might* in the asserted sentence has a new variable ω, and the same variable ω appears on *might* in the alternative. This is again assumed to be ensured by the syntax of alternatives. (34) will result in the following set of assignments.

$$\left\{ g' \;\middle|\; \exists g \in F \left(\begin{array}{l} g[\omega]g' \wedge g'(\omega) \subseteq \mathrm{Dox}_s \\ \wedge \forall w \in g'(\omega)(\mathbb{MOST}(\{\, o \in \mathscr{O} \mid o \in \mathscr{I}_w(\mathrm{book})\,\}) \\ \quad (\{\, o \in \mathscr{O} \mid o \in \mathscr{I}_w(\mathrm{book}) \wedge \langle j, o\rangle \in \mathscr{I}_w(\mathrm{read})\,\})) \\ \wedge \neg \forall w \in g'(\omega)(\mathbb{ALL}(\{\, o \in \mathscr{O} \mid o \in \mathscr{I}_w(\mathrm{book})\,\}) \\ \quad (\{\, o \in \mathscr{O} \mid o \in \mathscr{I}_w(\mathrm{book}) \wedge \langle j, o\rangle \in \mathscr{I}_w(\mathrm{read})\,\})) \end{array} \right) \right\}$$

In words, there is an epistemic possibility that John read most of the books where it is not the case that John read all of the books.[14] The SI here therefore corresponds to (7a), and the SI of the form (7b) cannot be derived in the present system.

4.2 Root Modals

Now, what about root possibility modals, which do give rise to SIs that $\neg\Diamond(\ldots\mathrm{all}\ldots)$, unlike epistemic modals and indefinite DPs? Although I do not have a satisfactory answer at the moment as to why root modals are different in this particular way from epistemic modals, the framework we are assuming at least offers a way to capture their behavior. Specifically, I propose that unlike epistemic possibility modals, root possibility modals always perform random assignment. This is shown by (35) for deontic possibility, where DEON is the set of deontically ideal worlds.[15]

[14]In the above representation, $\neg$ takes scope over the universal quantification over possible worlds, which is arguably too weak. However, assuming that this universal quantification is associated with a homogeneity requirement, the SI becomes adequately strong. That is, the homogeneity requirement says that either of the following is the case: (i) in all the worlds in $g'(\omega)$ John reads all of the books; or (ii) in none of the worlds does John read all of the books. Since the SI here is only compatible with (ii), and one concludes that, as desired. This assumption about homogeneity is not at all far-fetched, as the universal quantifier here is due to plural predication of possible worlds and plural predication in natural language generally gives rise to such homogeneity effects. For instance, *It is not the case that John read the books* seems to entail that John read none of the books.

[15]This, of course, is a gross oversimplification of the meaning of deontic modals. See Kratzer 1981, 1991 in particular. Although I do not see any obstacle in adopting Kratzer's

(35) $$F[\mathsf{allowed}^{\omega}(\mathsf{come}(j))] = \left\{ g' \;\middle|\; \begin{array}{l} \exists g \in F(g[\omega]g' \wedge g'(\omega) \subseteq \mathsf{DEON} \\ \wedge \forall w \in g(\omega)(j \in \mathscr{I}_w(\mathsf{come}))) \end{array} \right\}$$

This meaning will derive the desired reading for (23) that John is allowed to read most of the books and he is not allowed to read all of the books, which involves an SI of the form (7b). More specifically, after processing the asserted sentence *John is allowed*$^{\omega}$ *to read most of the books* against file F, we obtain the following file F':

$$F' = \left\{ g' \;\middle|\; \exists g \in F \left(\begin{array}{l} g[\omega]g' \wedge g'(\omega) \subseteq \mathsf{DEON} \\ \wedge \forall w \in g'(\omega)(\mathbb{MOST}(\{\, o \in \mathscr{O} \mid o \in \mathscr{I}_w(\mathsf{book})\,\}) \\ \quad (\{\, o \in \mathscr{O} \mid o \in \mathscr{I}_w(\mathsf{book}) \wedge \langle j, o \rangle \in \mathscr{I}_w(\mathsf{read})\,\})) \end{array} \right) \right\}$$

Now we process the negation of the alternative sentence *John is allowed*$^{\omega}$ *to read all of the books*, and obtain the following file:

$$\left\{ g' \in F' \;\middle|\; \neg \exists g'' \left(\begin{array}{l} g'[\omega]g'' \wedge g''(\omega) \subseteq \mathsf{DEON} \\ \wedge \forall w \in g''(\omega)(\mathbb{ALL}(\{\, o \in \mathscr{O} \mid o \in \mathscr{I}_w(\mathsf{book})\,\}) \\ \quad (\{\, o \in \mathscr{O} \mid o \in \mathscr{I}_w(\mathsf{book}) \wedge \langle j, o \rangle \in \mathscr{I}_w(\mathsf{read})\,\})) \end{array} \right) \right\}$$

Importantly, ω here is again used to perform random assignment. Consequently, each g' in this file maps ω to a set of deontically ideal worlds in which John reads most of the books, and additionally, it is ensured that there's no way to assign ω a set of deontically ideal worlds in which John reads all of the books, because such assignments are culled out by the SI.[16]

ideas in our current framework, I will assume the simplistic semantics here too keep the exposition simple. Also, this analysis does not predict that root modals cannot participate in modal subordination, as modal subordination is about anaphora about the domain of quantification. I do not represent the domain of quantification here explicitly, which would require a different variable and complicate the exposition. In a complete theory of modals and quantifiers, such domain variables need to be represented. See, for example, Brasoveanu 2007, 2010b,a. I thank Christopher Piñon for related discussion.

[16]If one believes that the embedded SI is also available for sentences like (23), one could resort to one's favorite way of accounting for embedded SIs. In the current set up, exh can simply take scope in the infinitival clause to yield this reading. Since the availability of embedded SIs is not the main concern of the present paper, I will remain uncommitted to this issue here.

5 Conclusions and Further Issues

In the present paper I have made two main observations: (i) sentences of the form ∃ . . . some/most . . . where ∃ is an indefinite DP or an epistemic possibility modal lack the negation of ∃ . . . all . . . as a (potential) SI, but (ii) this SI is observed when ∃ is a root modal. To account for (i), I pursued the following idea: indefinites DPs and epistemic modals introduce variables to the discourse, which denote new discourse referents in the asserted sentence but behave as anaphoric terms in the negated alternative sentences. As for the issue (ii), I proposed that root possibility modals do not introduce variables to the discourse. Rather, they are existential quantifiers, and always perform random assignment.

Admittedly, this account of (ii) is still preliminary, as it is essentially a lexical stipulation made just to account for what is observed and lacks independent justification. Differences between epistemic vs. root modals are a very well discussed topic (cf. Ross 1969, Perlmutter 1971, Jackendoff 1972, Brennan 1993, von Fintel & Iatridou 2003, Hacquard 2006, 2011), and I hope the present analysis will eventually relate to the insights offered by this body of literature, and lead to a deeper explanation of their syntax and semantics. This issue is left for future research.

Another remaining issue that is set aside in the present paper is the interactions between SIs and other types of quantifiers than indefinites. That is, it is natural to extend the ideas of the present paper to sentences like the following.

(36) a. 20% of the students read most of the books.
b. Most of the students read most of the books.

(37) a. John is likely to have read most of the books.
b. John has probably read most of the books.

The reason why I am not discuss these cases here is because those quantifiers come with their own SIs, giving rise to independent problems of multiple scalar items discussed by Fox (2007), Chemla (2009) and Romoli (2012) (as mentioned already in footnote 10). It is expected that the perspective of the present dynamic semantic account provides new insights into this issue, which is left for another occasion.

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The Reciprocity-Symmetry Generalization: Protopredicates and the Organization of Lexical Meanings

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Abstract This paper systematically analyzes the relations between logical symmetry and lexical reciprocity. A new generalization about these phenomena is uncovered, which is referred to as the *Reciprocity-Symmetry Generalization*. An analysis of this generalization leads to a new formal theory of lexical reciprocity. The theory builds on a new notion of *protopredicates*, which connects binary and unary meanings at the interface between the lexical items and mental concepts. Because of its foundational nature and plausibility for other languages besides English, the Reciprocity-Symmetry Generalization is conjectured to be a language universal. Although this generalization is new with this paper, it appears to have been silently sensed since early transformational works in the 1960s, without any general analysis. By uncovering this generalization and accounting for it, the present work removes considerable confusion surrounding the pertinent semantic questions.

Keywords reciprocity · collectivity · symmetry · plurals · thematic role

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1 Introduction

A binary predicate R is standardly called **symmetric** if for every x and y, the statement $R(x, y)$ is logically equivalent to $R(y, x)$. Examples for symmetric predicates in English include relational adjectives, nouns and verbs, as in the following equivalent sentences.

(1) a. Rectangle A is identical to Rectangle B $\Leftrightarrow$ Rectangle B is identical to Rectangle A.

b. Mary is John's cousin $\Leftrightarrow$ John is Mary's cousin.

c. Sue collaborated with Dan $\Leftrightarrow$ Dan collaborated with Sue.

Such truth-conditional equivalences lead formal semantic accounts to classify the binary predicates *identical to*, *cousin* (*of*), and *collaborate with* as symmetric (Partee 2008).

A fascinating property of symmetric binary predicates is their systematic homonymy with **reciprocal** predicates. For instance, the binary predicates in (1a–c) all have unary alternates that give rise to the following plural sentences.

(2) a. Rectangle A and Rectangle B are identical.
b. Mary and John are cousins.
c. Sue and Dan collaborated.

Almost all symmetric binary predicates like *identical to*, *cousin* (*of*) and *collaborate* (*with*) have unary alternates, as in (2).[1] However, the converse is not true. There is a considerable class of unary predicates that are intuitively reciprocal, but have a binary alternate that is not symmetric. For instance, consider the following sentences.

(3) a. Sue hugged Dan / Sue kissed Dan / Sue collided with Dan.
b. Sue and Dan hugged/kissed/collided.

The binary predicates in (3a) are obviously non-symmetric. For instance, Sue may have hugged or kissed Dan without him ever hugging or kissing her back. Similarly, *collide with* is also a non-symmetric relation: if Sue's car hit the rear of Dan's car while it was parked and he was sleeping on its back seat, you may truthfully assert that Sue's car collided with Dan's car, but not that Dan's car collided with Sue's car. Despite their non-symmetric behavior, the predicates *hug*, *kiss* and *collide* have reciprocal-looking collective usages, as illustrated in (3b). This fact challenges the common intuition that lexical reciprocity is somehow related to logical symmetry. Due to this challenge, and perhaps owing something to the exuberance in which the problem was introduced in Dong 1971, the semantic connections between symmetry and lexical reciprocity have remained somewhat obscure. This paper aims to remove a big part of the empirical obscurity and account for the emerging picture.

[1] English only has a handful of symmetric predicates that do not have such alternates: *near*, *far from* and *resemble* are notable examples (see section 6).

The paper is structured as follows. Section 2 makes some preliminary remarks about symmetry and reciprocity in language, and in truth-conditional semantics. Section 3 introduces a new empirical generalization about reciprocal alternations and their connections with (non-)symmetry. One kind of lexical reciprocity is characterized by "plain" equivalences, as between (1a–c) and (2a–c). By contrast, it is argued that with non-symmetric predicates, the connections between sentences, as in (3a) and the corresponding collective sentences in (3b) are not logical but preferential. These connections are referred to as "pseudo-reciprocity." The distinction between plain reciprocity and pseudo-reciprocity leads to a new empirical generalization, referred to as the *Reciprocity-Symmetry Generalization* (RSG): a reciprocal alternation shows a plain equivalence *if and only if* the binary form is symmetric.

Section 4 discusses some previous accounts and argues that they do not account for the RSG. Addressing this problem, section 5 develops a new theory of reciprocal alternations, inspired by Dowty's (1991) analysis of *protoroles*. In this theory, reciprocity alternations are viewed as the result of a derivational stage that intermediates between mental concepts and predicate meanings in the lexicon. This intermediate level is defined using abstract predicates referred to as *protopredicates*. Denotations of lexical predicates in plain alternations are derived by protopredicates that are associated with *collective concepts* like "Identity," "Cousinhood" or "Collaboration," which specify *sets of entities*. The respective protopredicate connects the two lexical predicates – the unary-collective predicate and the binary predicate – by a rule that explains the symmetry of the latter. By contrast, pseudo-reciprocal alternations are derived by protopredicates that are associated with two concepts: a collective concept and a binary concept. Such pairs of concepts – for example, a collective Hug vs. a binary-directional Hug – are logically independent, although they are regulated through lexical preferences – for example, a collective hug preferably, though not necessarily, involves two binary hugs. The conceptual connections between the two homonymous entries of verbs like *hug* are specified within one protopredicate, but these connections are distinguished from logical derivations in formal semantics.

Section 6 mentions some recent unpublished work providing new evidence for the proposed theory from irreducible collectivity and Hebrew reciprocal comitatives, and from experimental results about pseudo-reciprocal predicates like *hug* and *collide*.

2 On the Linguistic Expression of Symmetry and Reciprocity

The claim that pairs of sentences as in (1a–c) are "equivalences" invites a clarification about the difference between truth-conditional semantics and information structuring in natural language. Clearly, each of the two sentences in such pairs conveys something different about the participants' involvement. Thus, *A collaborated with B* implies that, from the point of view of the speaker, A and B have different capacities or statures. The implication is reversed in the sentence *B collaborated with A*. More vividly, perhaps: *Podolsky collaborated with Einstein* is a natural way of highlighting the work of the physicist Boris Podolsky on the EPR paradox. By contrast, *Einstein collaborated with Podolsky* might not convey the importance of the collaboration for Podolsky's career. Plausibly, such differences are not truth-conditional: it is hard to come up with contexts in which one of the sentences in such pairs is clearly true while the other one is clearly false. The differences between sentence pairs as in (1a–c) is commonly related to Figure-Ground effects and other non-truth-conditional phenomena (Talmy 1975, 2000, Tversky 1977, Dowty 1991, Gleitman et al. 1996). Thus, our claim that binary predicates as in (1a–c) are symmetric, as they are normally considered in formal logic, does not stand in opposition to further pragmatic considerations in cognitive semantics and cognitive psychology.

A similar remark holds with respect to the claim that the reciprocal sentences (2a–c) are equivalent to the respective sentences in (1a–c). For the same reasons discussed above, to say that *Podolsky collaborated with Einstein* is surely different than saying than the two physicists collaborated. And for the same reasons, the claim about the "equivalence" between the reciprocal sentences and their transitive correlates concerns the truth-conditions of these sentences, not their full informational content.

As a further clarification, it should be noted that the label "reciprocal" for sentences (2a–c) should not be understood as implying that they are somehow derived from equivalent reciprocal sentences like the following.

(4) Rectangle A and Rectangle B are identical to *each other*.

The relation between the binary use of the adjective *identical* in (1a) and its collective use in (2a) is a non-trivial lexical fact: the same phonological material – the word *identical* – has two syntactic and semantic functions. By contrast, the ability to use the pronominal expression *each other* in (4) as an argument of the relational adjective *identical to* is a simple fact about the way this pronoun works, which tells us little about the word *identical*. Virtually all binary predicates appear in reciprocal sentences like (4), whether or not they have a lexical-reciprocal entry. For instance, sentences like *Sue and Dan forgot each other* are perfectly OK due to the general properties of *each other* as a syntactic argument. However, the binary predicate *forget* has no lexical reciprocal correlate: strings like *Sue and Dan forgot*, to the extent that they are acceptable, involve not reciprocity, but an implicit argument (e.g., "forgot something relevant to the context of utterance"). This is only one of many distinctions between lexical reciprocity as in (2) and quantificational reciprocity as in (4). Some further distinctions are discussed in Carlson 1998, Dimitriadis 2008 and Siloni 2012, among others. Despite these distinctions, some confusions surrounding the term "reciprocity" are still widespread. Indeed, early transformational accounts, notably Gleitman 1965, assumed that a sentence like (2a) has (4) in its derivational history. Apparently, convictions that there must be some derivational relation between such sentences have persisted for over half a century. As a matter of fact, at present there is little evidence to support such views, which are also not represented in most recent work on quantificational reciprocity (Dalrymple et al. 1998, Kerem et al. 2009, Sabato & Winter 2012, Mari 2014, Poortman et al. 2016). The possible relation between lexical reciprocity as in (2) and quantificational reciprocity as in (4) is a complex topic, which is still poorly understood. Studying this problem is supplementary to, and partly dependent on, the main tenets of the present work.

3 The Reciprocity-Symmetry Generalization

To address the challenges for the theory of reciprocal predicates, we introduce a formal semantic criterion that distinguishes two sub-classes of such predicates. Reciprocal alternations with predicates like *identical*, *cousin* and *collaborate* are referred to as *plain reciprocity*. For instance, when characterizing the semantic relation between the predicates (*are*) *identical* and *identical to* as plain reciprocity, we rely on the following equivalence:

(5) A and B are identical
$\Leftrightarrow$ A is identical to B, and B is identical to A

The repetition of two "identical to" statements in (5) may seem unnecessary due to the symmetry of this predicate. However, it is required for generality, as explained below. To generalize the plain reciprocity pattern in (5), suppose that P is a unary-collective predicate and R is a binary predicate, such that both P and R are associated with the same morphological form. Due to the morphological relation between them, we classify P and R as *alternates*. For instance, for the adjective *identical*, P is the plural collective usage as in *A&B are identical*, whereas R is the alternate binary form *identical to*. To characterize the semantic alternation between P and R as plain reciprocity, we require the following:

(6) **Plain reciprocity (plainR):** For all x, y such that $x \neq y$:
$P(\{x, y\}) \Leftrightarrow R(x, y) \wedge R(y, x)$

In words: we say that plainR obtains between P and R if for every pair of entities x and y, the collective predicate P holds of the doubleton $\{x, y\}$ if and only if the binary predicate R holds between x and y in both directions.[2] Thus, due to the definition in (6), the equivalence in (5) characterizes the alternation of the predicate *identical* as plain reciprocity, where P is the unary-collective use of the predicate and R is the binary form *identical to*.

After stating the general condition of plainR alternations, let us now return to the redundancy we feel in (5). This redundancy is due to the symmetry of the binary predicate *identical to*. However, the general definition of plainR alternations in (6) does not assume anything about symmetry of the binary predicate R (see footnote 2). This is deliberately so, for symmetry of a binary predicate R should analytically be distinguished from

[2]Note that this does not mean that R is symmetric: it only means that the predicate R holds "symmetrically" between the x's and y's that satisfy $P(\{x, y\})$. For other x's and y's, the predicate R may hold in one direction only, hence (6) does not require R to be symmetric.

the sort of reciprocity we see in the corresponding collective predicate P. As we shall see below, it is possible to define artificial collective predicates that stand in plain reciprocity to non-symmetric binary predicates. Since we want the notion of plain reciprocity in (6) to be well-defined for all binary predicates, we do not assume anything about R's symmetry.

Notwithstanding, a deep connection between symmetry and reciprocity has been maintained by most previous works on the topic (see section 4 below). Here it is claimed that in fact, such a connection only exists for the reciprocal alternations that we classified as *plain* reciprocity. Although logic alone cannot account for such connections, I propose that the connection between plain reciprocity and symmetry is a valid empirical generalization. The part of this connection that we have so far observed is officially stated below.

(7) **Reciprocity-Symmetry Generalization (RSG, first version):** All binary predicates in natural language that take part in plainR alternations are truth-conditionally symmetric.

This generalization states that logical symmetry is a necessary property of any binary predicate in natural language that stands in a plainR alternation to a collective predicate. A major aim of this paper is to substantiate this generalization and account for it.

More examples for predicates that give rise to plainR alternations are given below.

(8) **Predicates in plainR alternations:**
Verbs: collaborate (with), talk (with), meet (with), marry, debate, match, rhyme (with)
Nouns: cousin (of), twin (of), sibling (of), neighbor (of), partner (of)
Adjectives: identical (to), similar (to), parallel (to), adjacent (to)

As expected by the RSG, the binary guises of all these predicates are logically symmetric. Note that some collective predicates in such alternations also have non-symmetric variants. For instance, unlike *talk with*, the form *talk to* is not symmetric, because Sue may be talking to Dan when he is not talking to her. As will be demonstrated below, the alternation between collective *talk* and *talk to* is *not* plainR. By contrast, the alternation between collective *talk* and *talk with* is plainR: in any sentence *A&B talk*, the reciprocal interpretation is equivalent with *A is talking with B and B is talking with A*.

The reciprocal interpretation is not the only reading of the verb *talk*. Like many other reciprocal predicates – for instance, *collaborate*, *similar*, and *friend*, among others – this verb also has a distributive interpretation. For instance, *Sue and Dan are talking* can be true when each of the two people is talking, but they are not talking with each other. This distributive use of intransitive *talk* should be analyzed as distinct from its reciprocal use. To see that, consider, for instance, the following example:

(9) Dan and Sue haven't been talking for ages.

Sentence (9) can be interpreted as true if Dan and Sue haven't had mutual communication for a long time, even if each of them has constantly been talking to other people. This means that the reciprocal interpretation of (9) can be true when the distributive interpretation is false: a sign of a genuine ambiguity between two readings. This ambiguity is plausibly related to the acceptability of sentences like *Sue is talking*.

By contrast, when reciprocal sentences are unacceptable in the singular – as in **Sue met* – the reciprocal reading is the only reading of the plural intransitive: *Sue and Dan met* can only mean that the two people met with each other. Thus, while intransitive *talk* is ambiguous between a reciprocal and a distributive reading, intransitive *meet* is unambiguously reciprocal. The reason for this contrast between different reciprocal predicates is not our main problem here, but it is useful to keep it in mind (see also Ginzburg 1990).

Let us now get back to generalization (7). One important caveat about this generalization concerns the lack of symmetry in gender with binary predicates like *sister* and *brother*, which support plainR alternations. For instance: A and B are sisters if and only if A is B's sister and B is A's sister. This means that the *sister* (*of*) alternation must be classified as plainR. However, the relation *sister of* clearly has non-symmetric usages: if Mary is some boy's sister, he obviously cannot be considered to be "Mary's sister." Schwarz (2006) and Partee (2008) show motivations for analyzing gender as a presupposition of kinship nouns, rather than as a truth-condition.[3]

[3] Schwarz argues that *Kim isn't his sister* implies that Kim is a female as much as *Kim is*

Similar proposals have been made for gender marking on other items (Sudo 2012). This means that the symmetry tests of the RSG should be applied to what Von Fintel (1999) calls “Strawson entailments”: entailments that hold between sentences provided that their presuppositions are satisfied. Indeed, Schwarz and Partee analyze *sister* and *brother* as “Strawson-symmetric”: symmetric in situations that satisfy their gender presuppositions. This removes the potential challenge to the RSG in (7), which only relies on truth-conditional symmetry. A similar caveat holds for any language that marks gender on predicates.[4]

We now move on to one outstanding challenge for theories of lexical reciprocity: the behavior of verbs like *hug*, *kiss* and *collide* as in (3). To show that such verbs do not support plainR, we should consider the following question: what are the semantic relations between the following two sentences?

(10) Sue and Dan hugged.

(11) Sue hugged Dan and Dan hugged Sue.

To be sure, sentence (11) does not entail (10) (Dong 1971, Carlson 1998): suppose that Sue hugged Dan while he was sleeping; then, after Dan woke up, Sue fell asleep and he hugged her while she was sleeping. In such a scenario (11) is true while (10) is false.

Furthermore, collective sentences like (10) do not uniformly entail “symmetric statements” like (11) either. As Winter et al. (2016) experimentally show, under certain circumstances, Dutch speakers may judge a sentence

his sister does, and suggests that the gender implication scopes over negation like other presuppositions.

[4]In English, there are not many gender-sensitive binary predicates that show a plainR behavior (though this phenomenon may have also developed with plural terms like *girlfriends*, *boyfriends*, *wives* and *husbands* when applied to gay couples). Gender-sensitive plainR alternations are more common in languages with grammatical gender. For instance, in Hebrew even the predicates *zehe le* (identical-SG.MASC to) and *zeha le* (identical-SG.FEM to) are gender-marked. Nevertheless, the Hebrew concept of identity is as symmetric as it can get in other languages: *Sue zeha le-Dan* holds iff *Dan zehe le-Sue* does. Similarly, both English and Hebrew support equivalences like *Sue is Dan’s sister* $\Leftrightarrow$ *Dan is Sue’s brother*. Reasonably, this happens because the symmetry of the concept “Sibling” is independent of its realization by a gender-neutral noun (which doesn’t exist in Hebrew).

like (10) as true while judging (11) to be false. For example, in the situation of figure 1, many speakers judged the Dutch translation of 'the girl and the woman are hugging' as true, while judging 'the woman is hugging the girl' as false. According to the standard semantics of conjunction, this judgement renders (11) false for such speakers, even though they accept (10) as true.

We conclude that it is hardly possible to derive the meaning of (10) from a conjunction like (11) of binary statements. Although there is much to say about the semantic relations between collective usages of verbs like *hug* and their binary usages, these relations are not fully definable using standard two-valued logic. The full semantic connection between the two forms of *hug* is more likely to be described by "soft" cognitive-conceptual principles, rather than by classical logical rules (see section 6).

Figure 1

We refer to all collective-binary alternations that do not satisfy the plainR characterization in (6) as **pseudo-reciprocity** (pseudoR). The relation between the two usages of *hug*, *kiss* and *collide* is an example for this kind of alternation. Another example is the predicate *be in love*. If A is in love with B and B is in love with A, neither of them has to be aware of the other's feelings, or even know that the other one knows her. In such situations, the love relations between the two people are not accompanied by "collective intentionality" (a term due to Searle 1990). Thus, the sentence *A&B are in love* misses a critical ingredient of its collective interpretation, and can hardly be considered true. In such an "independent love" situation, the sentence is only true under its distributive-existential interpretation "A is in love (with someone) and B is in love (with someone)." Similarly, if A is talking to B and B is talking to A, the collective interpretation of sentence *A&B are talking* is unacceptable if A and B are not intentionally engaged in a talk, for example, because they are not listening to each other.[5] Thus, the collective reading of intransitive *talk* and

[5]Roberto Zamparelli (pers. comm.) suggests imagining a situation in which A is talking to B and B is talking to A over the phone, in an attempt to conduct a phone talk. Suppose that the line is bad and neither of them is hearing the other, while neither of them is aware of the problem. In such a situation, the collective reading of the sentence *A&B are talking* is likely to be judged as false.

the binary form *talk to* are in a pseudoR alternation. The *talk* (*with/to*) case illustrates that the same unary-collective predicate – in this case *talk* – may show different plainR/pseudoR alternations with different binary predicates. Some languages support such multiple plainR/pseudoR alternations more regularly than English (see section 6).[6]

Another example for a pseudoR alternation appears with the Hebrew verb *makir* ('knows', 'is familiar with', 'has heard of'). Consider for instance the following sentence.

(12) morrissey *makir et* hod ma'alata, ve-hod ma'alata *makira et* morrissey
'Morrissey *knows*-MASC ACC Her Majesty, and Her Majesty *knows*-FEM ACC Morrissey'

Sentence (12) is most probably true of the two celebrities, at least when *makir* is interpreted in the sense of 'has heard of'.[7] However, this does not yet support the truth of the following sentence.

(13) morrissey ve-hod ma'alata *makirim*
'Morrissey and Her Majesty *know*-PLUR (= are acquainted with each other)'

Sentence (13) entails a personal acquaintance between Morrissey and Her Majesty, whereas (12) does not: if Morrissey and the queen have never met or talked, (13) is false while (12) is still likely be true. Note that unlike what we saw with the English predicates *be in love* and *talk*, sentences like (13) only have a collective interpretation and no distributive interpretation. This is because the verb *makir* does not tolerate singular subjects with null objects (e.g., **morrissey makir* 'Morrissey knows'). Therefore, the plural intransitive use of the verb *makir* in (13) is unambiguously collective, and only has the sense 'be in an acquaintance relation.'

To sum up, pseudoR alternations are distinguished from plainR alternations in that they do not show the equivalence in (6). Furthermore,

[6]In English, a similar but subtler contrast is found between transitive *meet* and *meet with*. Witness the contrast in *A met (with) B at the station* (Dixon 2005:361–362).

[7]Morrissey himself used this sense of *know* in a song from 1986: "So I broke into the Palace/With a sponge and a rusty spanner/She said: 'Eh, I know you, and you cannot sing'/I said: 'that's nothing – you should hear me play piano'" (The Smiths, *The Queen is Dead*).

for most of the predicates showing pseudo-reciprocity, it is questionable if there is any complete logical description of the semantic relations between the two forms. This lack of regularity hardly deserves the title "reciprocal." The label *pseudo-Reciprocity* is intended to underline this point.

The list below summarizes some of the predicates that show the pseudoR alternation.

(14) **Predicates in pseudoR alternations:** talk (to), (fall/be) in love (with), hug, touch, embrace, pet, fuck, fondle, box, *makir* (Hebrew 'know')

All the binary usages of these pseudoR predicates are non-symmetric. This justifies the following strengthening of the generalization in (7).

(15) **Reciprocity-Symmetry Generalization (RSG, final version):** A reciprocal alternation between a unary-collective predicate P and a binary predicate R is plainR if and only if R is truth-conditionally symmetric.

This strengthened version of the RSG adds to (7) the requirement that if the reciprocity alternation between P and R is not plainR – that is, it is qualified as pseudo-reciprocity – then R is not symmetric. Thus, plainR alternations characterize precisely those symmetric binary relations that have a reciprocal alternate.[8]

The RSG is linguistically revealing because it is not logically necessary. A way to show it is by inventing artificial predicate meanings that would violate this principle. For instance, suppose that the transitive verb *hug* had a morphological alternate *Xhug* with the unary-collective meaning defined in (16) below.

(16) Let *Xhug* have the meaning 'hug each other, but not necessarily at the same time.'

[8]The RSG in its formulation in (15) is neutral with respect to symmetric binary predicates like *resemble*, *near* and *far from*, which have no reciprocal alternates in English. Section 6 refers to a more speculative generalization than the RSG: that *all* binary predicates stem from collective concepts, even when those concepts are not realized as collective predicates in the language under consideration. For instance, Greek and Hebrew do have some reciprocal correlates corresponding to these symmetric binary concepts.

This collective predicate would be in a plainR alternation to the non-symmetric transitive verb *hug*. This is because of the equivalence *A&B Xhugged* ⇔ *A hugged B and B hugged A*. Having such a plainR alternation with a non-symmetric predicate like *hug* would violate the first part of the RSG (the "only if" direction of (15)). Conversely, we can also define a hypothetical symmetric binary predicate in a pseudoR alternation to a unary-collective predicate. For instance, consider a hypothetical transitive construction *Xtalk to*, which would stand in a morphological alternation to the collective intransitive verb *talk*. Suppose that such a *talk* construction had the meaning of the binary predicate defined in (17).

(17) Let x *Xtalk to* y mean 'x talks to y and y talks to x (without necessarily listening to each other).'

The sentence *A Xtalked to B and B Xtalked to A* would not entail the collective reading of *A&B talked*. Such a case of pseudoR alternation with a symmetric binary predicate like *Xtalk* would also go against the RSG (the "if" direction of (15)).

These two artificial cases illustrate that both directions of the RSG are not logically necessary. Thus, relying on our assumption that the RSG generally holds, we should look for a linguistic theory of the correlation that it describes. This is the topic of the next sections.

4 Previous Accounts and the RSG

Early transformational accounts proposed two different strategies for treating reciprocal alternations. Gleitman (1965) proposed a deletion rule, where eliminating *each other* in binary constructions leads to the unary-collective entry. Lakoff & Peters (1969) proposed a conjunct movement rule that maps *and* conjuncts to PP adjuncts. Semantically, we can describe Gleitman's rule as an operator **U** that maps any binary relation R to the following unary-collective predicate:

(18) $\mathbf{U}(R) = \lambda A.\forall x, y \in A.x \neq y \rightarrow R(x, y)$

Lakoff & Peters' proposal can be mimicked by an operator **B** that maps any unary-collective predicate P to the following binary predicate:

(19) $\mathbf{B}(P) = \lambda x.\lambda y.P(\{x, y\})$

Both operators analyze plainR alternations like (5) correctly. However, in both works it was incorrectly assumed that all binary predicates in reciprocal alternations are symmetric. This prediction is in agreement with the RSG in all that concerns plainR alternations. Furthermore, while Gleitman's account has to stipulate logical symmetry, Lakoff & Peters's rule successfully predicts symmetry as a corollary: trivially, $\mathbf{B}(P)$ is symmetric for every collective predicate P. Somewhat unfortunately, in subsequent linguistic work, the logical term "symmetric predicate" has often been confused with the much vaguer linguistic notion of "standing in a reciprocal alternation" (see Partee 2008 for remarks on some of the terminological issues). This confusion obscured the observation, originally made in Dong 1971, that neither Gleitman (1965) nor Lakoff & Peters (1969) treat the alternations that we here classify as pseudoR. For instance, the **U** operator would wrongly analyze *A&B hugged* as meaning 'A&B hugged each other', ignoring the simultaneity requirement of intransitive *hug*.[9] Conversely, the **B** operator would analyze *A hugged B* as meaning 'A&B hugged', ignoring the non-symmetry of the former. Gleitman and Lakoff & Peters did not consider such cases of pseudoR, and as a result, their theories are empirically incomplete. In a later work, Ginzburg (1990) treated plainR alternations using rules similar to **U** and **B**, proposing linguistic criteria for determining which of them should be used in each case: (in)felicity with reflexive arguments (*A is similar to/*met herself*) and null complements (*A is similar/*met*). Ginzburg did not discuss predicates like *hug* and *kiss*, and his criteria are orthogonal to the plainR/pseudoR distinction. Like the transformational works from the 1960s, Ginzburg's proposal does not account for pseudoR alternations or the plainR/pseudoR distinction.

Later in the 1990s, non-symmetric predicates like *hug* and *kiss* have regained considerable linguistic attention. Gleitman et al.'s (1996) experimental study involved two experiments asking participants to (i) grade various predicates for symmetry, and (ii) indicate how close in meaning reciprocal sentences like *A&B met/kissed* are to the same sentences with an overt *each other*. Gleitman et al. report no correlation between the

[9] With Hebrew *makir* ('know') the counterexample to Gleitman's account would not rely on tense: *A&B makirim* ('A&B are acquainted with each other') would be interpreted by the **U** as equivalent to 'A knows B and B knows A.' As examples (12)–(13) demonstrate, such an analysis would be inadequate.

results, but note (p. 354) that "it becomes progressively harder to find distinguishing events and states [between the unary predicate and the binary predicate with an overt reciprocal – Y.W.] as we ascend the symmetry ladder." This intuition also underlies the RSG. Gleitman et al. do not develop the point further than that. Rather, they conclude that "symmetry" is a lexical-semantic property of certain predicates, distinct from standard logical symmetry. Gleitman et al. illustrate this claim by pairs of binary predicates like *kiss/love* and *collide with/hit*, which are all logically non-symmetric, but where only the first predicate in each pair takes part in reciprocal alternations. Gleitman et al. propose (pp. 355–356) that because verbs like *kiss* and *collide* show the alternation, their binary guises are perceived as "more symmetric" than predicates like *love* and *hit*. While this may be correct, it does not explain why the non-symmetric predicates like *hug* and *kiss* do not support plain reciprocity like the logically symmetric predicates like *marry* or *match*, and only show pseudo-reciprocal relations with their unary-collective alternates (see section 3, the discussion following examples (10) and (11)).

More recent works have concentrated on the connection between thematic roles, reciprocity and events (Carlson 1998, Dimitriadis 2008, Siloni 2012). These works all find interesting distinctions between binary predicates and collective predicates in pseudoR alternations. Notably, as Carlson observes, sentences like *A&B hugged each other five times* are interpreted differently than *A&B hugged five times*. Carlson concludes that the unary-collective predicate must be treated as basic, rather than as derived from the binary predicate. As we show below, this insight, which also underlies Lakoff & Peters' older work, is useful as a basis for analyzing the origins for the RSG, but without further assumptions it does not explain it. Dimitriadis (2008) and Siloni (2012) propose different rules for interpreting reciprocal predicates. These rules are meant as general accounts of the alternation. Therefore, they also do not account for the RSG or the plainR/pseudoR distinction.

In another semantic study of reciprocity, Mari (2014) analyzes sentences like *The boys followed each other into the room*. The non-symmetric predicate *follow into* is furthermore *a*symmetric.[10] Mari's work argues for

[10] Asymmetric binary predicates like the transitive verb *follow* require non-symmetry

systematic generalizations about asymmetry with overt reciprocals like *each other*, but it does not address lexical reciprocity. Asymmetric predicates like *follow* usually reject reciprocal alternations in the lexicon. See, for example, the unavailability of reciprocity in *The boys followed into the room*.[11] Like Mari's work, other recent works on *each other* (e.g., Dalrymple et al. 1998, Kerem et al. 2009, Sabato & Winter 2012, Poortman et al. 2016) also do not address the relations between such quantifiers and lexically reciprocal predicates.

5 Protopredicates and the RSG

This section develops a formal account of reciprocal alternations, which derives the RSG as a corollary. We start from the common intuition that natural language predicates classify eventualities, and that arguments of predicates represent participants in those eventualities according to different thematic roles (traditionally referred to as "agent," "patient," etc.). No special assumptions are made about the semantic properties of these roles, or the way they are hard-coded into predicate meanings. In consistency with the agnostic approach in Dowty 1991, we may think of thematic roles according to what Dowty calls *protoroles*: sets of "entailments of a group of predicates with respect to one of the arguments or each." Following this approach, a formal level of predicate meaning representation is defined, using what I will refer to as *protopredicates*: abstract predicates that make thematic distinctions between entities insomuch as they are relevant for describing logical entailments. Non-symmetric binary predicates like *attack* must logically distinguish their arguments. Accordingly, the protopredicates corresponding to such predicate are binary like their surface forms. By contrast, symmetric binary predicates like *cousin*

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under all situations. Thus, a situation in which A follows B into the room must be a situation in which B is not following A into the room. Non-symmetric verbs like *hug* are not asymmetric: it is, of course, possible (and even likely) for A to hug B at the same time when B hugs A.

[11]One asymmetric predicate that does appear in English as a collective entry is *stacked*, as in *The two chairs are stacked*. Hebrew has another asymmetric predicate that can act collectively: *okev* ('consecutive'), as in *3 ve-4 hem misparim okvim* (3 and 4 are numbers consecutive-PLUR, 'one of the numbers 3 and 4 follows the other'). This rare kind of example has not been studied in previous work, and remains a challenge for further research.

of do not make any logical distinctions between their arguments. Therefore, the protopredicates deriving symmetric predicates are assumed to be unary-collective, and derive both binary-symmetric forms like *cousin of* and unary-collective forms like *cousins*. This immediately accounts for plainR alternations. The protopredicates for pseudoR alternations as with the verb *hug* are defined as denoting unions of binary relations and unary-collective relations. This correctly avoids any logical connection between forms such as the two entries for English *hug*. After defining the details of this semantic architecture, it is shown that it expects the RSG as a formal corollary.

Natural language predicates – verbs, nouns and adjectives – can all be seen as names of *concepts*, which speakers use for categorizing situations in their environment. The notion of "thematic role" is based on typical properties of participants in the situations categorized by a predicate concept. For instance, one of the participants in a situation that we may call an *attack* is typically active, hostile, forceful, violent, etc. The other participant is viewed as more passive. A participant of the first kind is traditionally called an "agent," whereas a participant of second kind is called a "patient." To avoid prejudice, we here do without these classical notions. What is important for our purposes is that any situation that we might classify as an *attack* invites us to distinguish between two different "roles" of the participants. Addressing the precise nature of such distinctions would involve big questions like the specification of the events that fall under concepts like "Attack." This enterprise is far beyond the focus of this paper. Fortunately, to develop a theory of reciprocal alternations, we only need to acknowledge the mere existence of role distinctions. Thus, we assume that in any situation that is categorized as falling under the concept "Attack," there are two designated objects, which are distinguished by their "role" in that situation. For generality, we here use the abstract labels "$\mathbf{r}_1$" and "$\mathbf{r}_2$" for these two roles. Further specifics about the conceptual-semantic content of these labels are irrelevant for our purposes here.

In general, each situation that is categorized by a given concept must have one or more participants in some or other "role" that is specified by that concept. In principle, there may be overlaps between the sets of participants of different roles. For instance: with a binary predicate like *attack*, a person may attack herself, in which case two different roles are assigned to the same entity.[12]

For further illustration, (20) below informally describes some different attack situations, with participants A, B, C and D, and their assumed roles.

(20) Attack 1: A has role $\mathbf{r}_1$ ("agent"); B has role $\mathbf{r}_2$ ("patient").
Attack 2: D has role $\mathbf{r}_1$; C has role $\mathbf{r}_2$.
Attack 3: E has both roles $\mathbf{r}_1$ and $\mathbf{r}_2$.

These situations support the following sentences, respectively.

(21) a. A attacked B.
b. D attacked C.
c. E attacked herself.

To describe situations as in (20), we define what we here call a *protopredicate*.[13] A protopredicate is a relation that relates participants in situations not according to their argument position, but according to their semantic roles. In the case of the protopredicate for the verb *attack*, each syntactic argument specifies a different role, hence the protopredicate is fully aligned with the linguistic form. Accordingly, the protopredicate that corresponds to the situations in (20) is simply the following binary relation:

(22) $\{\langle \mathrm{A}, \mathrm{B}\rangle, \langle \mathrm{D}, \mathrm{C}\rangle, \langle \mathrm{E}, \mathrm{E}\rangle\}$

This is the traditional analysis using binary relations for transitive verbs like *attack*. More generally: all protopredicates for non-symmetric binary forms are assigned the type b ("binary"). We use the notation $\mathbf{P}^b$ to indicate that a protopredicate $\mathbf{P}$ is of type b. Thus, the meaning of the verb

[12] A more complicated case of overlap between roles appears when Sue and Dan form a group that attacks itself. To simplify the analysis of reciprocity, we here ignore such situations that involve group arguments. The question of the right representation of such situations using collective protopredicates is related to the general semantic question of how to classify groups and plurals in the lexicon, which goes beyond the scope of this paper. See Dowty 1987, Winter 2002 for a distinction between two types of collectivity. The present paper addresses the only type of collectivity that is invoked by reciprocal predicates in their unary-collective guise – the type that Winter refers to as "set predicates."

[13] The term implies the intuitive connection with Dowty's protoroles, but the current treatment does not presuppose Dowty's conceptions, and can also be implemented under other approaches to thematic roles. I thank Chris Piñón for pointing this out to me.

attack is described by a binary protopredicate $\mathbf{attack}^b$.[14] The binary relation in (22) is one possible denotation of the protopredicate $\mathbf{attack}^b$. Other non-symmetric transitive verbs (*admire, see*) and non-symmetric relational nouns and adjectives (*father of*, *boss of*, *fond of*) receive a similar treatment using binary protopredicates.

Here it should be noted that *b*-type protopredicates like **attack** do definitely *allow* situations that do not distinguish participants in terms of their roles. For instance, in one of the situations described in (22) above, E attacked herself. In this situation, E has both roles $\mathbf{r}_1$ and $\mathbf{r}_2$. In models where all attack events are such self-attacks, the two roles are not extensionally distinguished. However, as illustrated by the other situations in (22), there is no restriction that *forces b*-type protopredicates to show "role symmetry" in all models. For this reason, transitive verbs like *attack* are correctly treated as non-symmetric: in some models (though not necessarily in all models) they denote non-symmetric binary relations.

Something quite different must be said about relational expressions like *marry*, *collaborate*, *friend* (*of*) or *identical* (*to*). The situations that such expressions categorize are "inherently symmetric": the participants in them cannot be logically distinguished in terms of their roles. Thus, although sentences like *Sue collaborated with Dan* or *Sue married Dan* give the impression that Sue was somehow more active or prominent, we make no logical distinction between her role and Dan's role in the situation. Accordingly, in such cases we let each participant receive one and the same role. Because all participants are treated as equal, it is not important to decide if this role is "agent-like," "patient-like," etc. For neutrality, we denote such roles "$\mathbf{r}_{1\text{-}2}$," and intuitively refer to it as "collective".[15]

For example, let us consider the following marriage situations:

(23) Marriage 1: Each of A and B has the role $\mathbf{r}_{1\text{-}2}$.

[14] The same protopredicate would also be useful for nouns like *attack* (*of*) and *attacker*. The analysis should be adjusted to deal with event arguments, a point that is ignored here for the sake of simplicity. However, events fit into the current framework without special problems.

[15] Working within a specific theory of syntax and the lexicon, Siloni (2012) uses an operation of "bundling" for *deriving* an agent-patient role for reciprocal predicates, but I am not sure that there are semantic motivations for such a rule, or if its meaning could be defined in any general way.

Marriage 2: Each of C and D has the role $\mathbf{r}_{1\text{-}2}$.

This summarizes marriages between A and B and between C and D, which are described by the following sentences.

(24) a. A&B married (alternatively: *A married B*, or *B married A*).
b. C&D married (alternatively: *C married D*, or *C married D*).

The protopredicate corresponding to these two marriages is the following:

(25) $\{\{A, B\}, \{C, D\}\}$

More generally, in each situation describing a monogamic marriage, we assume that the bride and groom form one set of participants, whose members are not distinguished by their roles. Such protopredicates, which only assign the collective role $\mathbf{r}_{1\text{-}2}$, are called "collective" and are assigned the type c. In general, a protopredicate $\mathbf{P}$ of type c is denoted $\mathbf{P}^c$. For both intransitive and transitive guises of the verb *marry*, we employ one and the same collective protopredicate, denoted $\mathbf{marry}^c$. The collectivity of the protopredicate $\mathbf{marry}^c$ is viewed as the origin for the inherent symmetry of the transitive verb *marry*: since the protopredicate does not distinguish different roles, we expect all participants to be equally licensed in different argument positions.

As we shall see below, the postulation of collective protopredicates allows us to immediately derive plainR alternations, similarly to Lakoff & Peters' proposal. How about pseudoR alternations? To account for these alternations, we need to also characterize protopredicates for verbs like *hug*. Such protopredicates are treated as unions of b-type and c-type protopredicates. To see what that means, let us reconsider the two guises of the verb *hug*. In its collective guise, it is very much like *marry*: it has two participants with no difference in their roles. Thus, the sentence *Sue and Dan hugged* does not grammatically convey any difference between the activities of the two people. By contrast, in the sentence *Sue hugged Dan*, the non-symmetric transitive verb makes a role distinction: Sue was active and Dan was (possibly) passive. To describe situations with these two different senses of *hug*, we employ a "mixed" collective-binary type for protopredicates. Protopredicates of this type describe situations like the following.

(26) Hug 1: A has role $\mathbf{r}_1$ and B has role $\mathbf{r}_2$.
Hug 2: B has role $\mathbf{r}_1$ and A has role $\mathbf{r}_2$.
Hug 3: Each of C and D has three roles: $\mathbf{r}_1$, $\mathbf{r}_2$ and $\mathbf{r}_{1\text{-}2}$.
Hug 4: Each of E and F has role $\mathbf{r}_{1\text{-}2}$, and in addition, E has role $\mathbf{r}_1$, and F has role $\mathbf{r}_2$.

We may think of $\mathbf{r}_1$ as "agent," of $\mathbf{r}_2$ as "patient," and of $\mathbf{r}_{1\text{-}2}$ as "collective." Under this interpretation, hugs 1 and 2 in (26) are situations where one participant is active and the other is passive. Hug 3 is a prototypical "collective reciprocal hug": the two participants are collectively engaged ($\mathbf{r}_{1\text{-}2}$), and they are both actively engaged and passively engaged (roles $\mathbf{r}_1$ and $\mathbf{r}_2$). By contrast, Hug 4 is an atypical "collective non-reciprocal hug": both participants have the collective role $\mathbf{r}_{1\text{-}2}$, but only one of them is actively hugging the other one (see figure 1). The situations described in (26) support the following sentences, respectively:

(27) a. A hugged B.
b. B hugged A.
c. C&D hugged; C hugged D; D hugged C.
d. E&F hugged; E hugged F.

The protopredicate corresponding to the situations in (26) is made of the following items, possibly mixing sets and ordered pairs:

- Hug 1 corresponds to the ordered pair $\langle A, B\rangle$.
- Hug 2 corresponds to the ordered pair $\langle B, A\rangle$.
- Hug 3 corresponds to the set $\{C, D\}$ and the pairs $\langle C, D\rangle$ and $\langle D, C\rangle$.
- Hug 4 corresponds to the set $\{E, F\}$ and the ordered pair $\langle E, F\rangle$.

In sum, we get the following denotation for the protopredicate:

(28) $\{\langle A, B\rangle, \langle B, A\rangle, \{C, D\}, \langle C, D\rangle, \langle D, C\rangle, \{E, F\}, \langle E, F\rangle\}$

The example in (28) mimics "collective hugs" using sets such as $\{C, D\}$ and $\{E, F\}$, and "binary hugs" using ordered pairs such as $\langle A, B\rangle$ and $\langle C, D\rangle$. To distinguish such "mixed" protopredicates from *b* and *c* protopredicates, we use the type *bc*. Thus, the protopredicate for the verb *hug*, in both its transitive and intransitive guises, is denoted $\mathbf{hug}^{bc}$.[16]

[16]Note that unlike binary and collective protopredicates, a "mixed" binary/collective

Let us now see how the three types of protopredicates – b, c and bc – are interpreted, and derive denotations of lexical predicates. The general definition (29) below formally specifies protopredicate denotations. In this definition, the notation $\wp^2(E)$ stands for the set $\{A \subseteq E : |A| = 2\}$ of all doubleton subsets of E, that is, all the subsets of E that are made of precisely two members. For convenience, this definition ignores sets of more than two members, although extending it for such cases of collectivity is straightforward.

(29) Let **P** be protopredicate of type b, c or bc. Let E be a non-empty set of entities. A **denotation** of **P** over E contains at least one of two parts: a Binary part and Collective part, denoted $[\![\mathbf{P}]\!]^B$ and $[\![\mathbf{P}]\!]^C$, respectively. These parts are defined below for protopredicates of the three types b, c and bc.

$\mathbf{P}^b$:	$[\![\mathbf{P}^b]\!]^B \subseteq E^2$	$[\![\mathbf{P}^b]\!]^C$ is undefined
$\mathbf{P}^c$:	$[\![\mathbf{P}^c]\!]^B$ is undefined	$[\![\mathbf{P}^c]\!]^C \subseteq \wp^2(E)$
$\mathbf{P}^{bc}$:	$[\![\mathbf{P}^{bc}]\!]^B \subseteq E^2$	$[\![\mathbf{P}^{bc}]\!]^C \subseteq \wp^2(E)$

This definition generalizes what is illustrated in (22), (25) and (28) above. For the predicate $\mathbf{attack}^b$, the denotation (22) only contains pairs, and no collections. For the predicate $\mathbf{marry}^c$, the denotation (25) only contains collections, and no pairs. For the predicate $\mathbf{hug}^{bc}$, the denotation (28) contains both collections and pairs.

From denotations of protopredicates, we derive typed denotations of actual predicates in the lexicon. Specifically: from the denotation of the protopredicate **attack**, we derive a denotation for the transitive verb *attack*; from the denotation of **marry**, we derive denotations for the transi-

protopredicate may have a couple of items per situation, as it is the case for the collective Hugs 3 and 4 in (26), which contribute both sets (e.g., {C, D}) and ordered pairs (e.g., ⟨C, D⟩) to the protopredicate denotation in (28). This multiple use of situations is not represented in the collection in (28). However, when we add events to the semantic system, we must make sure to index items like {C, D}, ⟨C, D⟩ and ⟨D, C⟩ in (28) using the same event – the one entity that corresponds to Hug 3 in (26). By contrast, the pairs ⟨A, B⟩ and ⟨B, A⟩ in Hugs 1 and 2 should be indexed by different events. It is important to keep to this method when dealing with sentences that count events. For instance, the sentence *A&B hugged* only reports one hug, not two or three, even though it is always asserted when *A hugged B* and/or *B hugged A* hold.

tive and intransitive guises of the verb *marry*; from the denotation of **hug**, we derive denotations for the transitive and intransitive guises of the verb *hug*. In most cases this is quite straightforward, as illustrated below.

1. *Collective predicates*: The intransitive verb *marry* denotes the "collective" (C) part of the denotation of the protopredicate **marry**, which is the whole denotation. The intransitive verb *hug* denotes the C part of the denotation of the protopredicate **hug**, which may often be only one part of this predicate's denotation. For instance, from (28) we only select the sets $\{\mathrm{C},\mathrm{D}\}$ and $\{\mathrm{E},\mathrm{F}\}$ for the intransitive guise of *hug*.
2. *Binary non-symmetric predicates*: The transitive verb *attack* denotes the "binary" (B) part of the denotation of the protopredicate **attack**, that is, the whole denotation. The transitive verb *hug* denotes the B part of the denotation of the protopredicate **hug**. Thus, from (28) we select the pairs $\langle \mathrm{A},\mathrm{B}\rangle$, $\langle \mathrm{B},\mathrm{A}\rangle$, $\langle \mathrm{C},\mathrm{D}\rangle$, $\langle \mathrm{D},\mathrm{C}\rangle$ and $\langle \mathrm{E},\mathrm{F}\rangle$ for the transitive guise of *hug*.

The b protopredicate **attack** derives no intransitive collective entry, since its C part is undefined. By contrast, for the c protopredicate **marry** we do have a method for deriving a transitive entry from the C part. This illustrates a third strategy for *binary-symmetric predicates*. It is similar to the transformational rule proposed by Lakoff & Peters (cf. (19)):

3. The transitive verb *marry* denotes the set of pairs:
   $\{\langle x,y\rangle : \{x,y\} \in [\![\mathbf{marry}^c]\!]^C\}$.

In words, these are the pairs whose elements constitute doubletons in the denotation of the protopredicate **marry**. In (25), those pairs are $\langle \mathrm{A},\mathrm{B}\rangle$, $\langle \mathrm{B},\mathrm{A}\rangle$, $\langle \mathrm{C},\mathrm{D}\rangle$ and $\langle \mathrm{D},\mathrm{C}\rangle$. Note that such a denotation is by definition symmetric, as explained in section 4 in relation to Lakoff & Peters's proposal.

The last strategy above, which was illustrated for the c-type protopredicate **marry**, is also useful for bc protopredicates like **hug**. In many languages, pseudo-reciprocals like *hug* are associated with an entry "hug with," where "A hugs with B" logically means the same as *A&B hug*. For English, we observed a similar strategy with the verb *talk with*: in contrast to the non-symmetric item *talk to*, which stands in a pseudoR alternation to collective *talk*, the symmetric binary predicate *talk with* stands in a plainR alternation to this collective predicate. Greek and Hebrew are languages that have a more productive "comitative" strategy for deriving verbs in such plainR alternations to collective predicates (see section 6). Formally, such binary "hug with" or *talk with* predicates are derived from *bc* protopredicates in the same way that transitive *marry* is derived above from the *c* protopredicate **marry**. For instance, if **hug** is a *bc* protopredicate with the set {A, B} and the pairs ⟨A, B⟩ and ⟨C, D⟩, then a binary verbal form "hug with" will contain the pairs ⟨A, B⟩ and ⟨B, A⟩: the two ordered pairs for whose members a "collective hug" is encoded by a set in the protopredicate. By contrast, the denotation of the transitive verb *hug* will contain ⟨A, B⟩ and ⟨C, D⟩: the two ordered pairs that encode "directional hugs" in the protopredicate. This accounts for the observation by Winter et al. (2016) that a situation as in figure 1 is a collective hug, despite the lack of one directional hug. In this sense, binary relations like "hug with" and *talk with* behave similarly to the intransitive-collective usages of *hug* and *talk*, rather than to the binary usages of *hug* and *talk to*.

To summarize, three different strategies are used for deriving denotations of predicates from denotations of protopredicates:

- A unary-collective strategy (UC): with *c* and *bc* protopredicates.
- A binary non-symmetric strategy (BNS): with *b* and *bc* protopredicates.
- A binary symmetric strategy (BS): with *c* and *bc* protopredicates.

Specifically, when applied to the protopredicates in (22), (25) and (28), these strategies derive denotations of transitive (*tr*) and intransitive (*iv*) verbs, as described below ("xy" abbreviates "$\langle X, Y\rangle$"):

attack^b: From the protopredicate denotation $\{ab, dc, ee\}$ in (22) we derive:
UC: –
BNS: $[\![\, attack_{tv}]\!] = [\![\mathbf{attack}^b]\!]^B = \{ab, dc, ee\}$
BS: –

marry^c: From $\{\{a, b\}, \{c, d\}\}$ in (25) we derive:
UC: $[\![marry_{iv}]\!] = [\![\mathbf{marry}^c]\!]^C = \{\{a, b\}, \{c, d\}\}$
BNS: –
BS: $[\![marry_{tv}]\!] = \{xy : \{x, y\} \in [\![\mathbf{marry}^c]\!]^C\} = \{ab, ba, cd, dc\}$

$\mathbf{hug}^{bc}$: From $\{ab, ba, \{c,d\}, cd, dc, \{e,f\}, ef\}$ in (28) we derive:
UC: $[\![hug_{iv}]\!] = [\![\mathbf{hug}^{bc}]\!]^C = \{\{c,d\},\{e,f\}\}$
BNS: $[\![hug_{tv}]\!] = [\![\mathbf{hug}^{bc}]\!]^B = \{ab, ba, cd, dc, ef\}$
BS: $[\![hug\_with]\!] = \{xy : \{x,y\} \in [\![\mathbf{hug}^{bc}]\!]^C\} = \{cd, dc, ef, fe\}$

Generalizing this example, we get the following definition for the three general derivational strategies.

(30) Let $\mathbf{P}$ be a protopredicate of type b, c or bc, with a denotation $[\![\mathbf{P}]\!]$. From $\mathbf{P}$ we derive a collective predicate denotation $P^{uc}_{\mathbf{P}}$ and two binary predicate denotations $R^{bns}_{\mathbf{P}}$ and $R^{bs}_{\mathbf{P}}$. This is defined as follows:

$P^{uc}_{\mathbf{P}} = [\![\mathbf{P}]\!]^C$ = the collective part of $\mathbf{P}$, if defined
$R^{bns}_{\mathbf{P}} = [\![\mathbf{P}]\!]^B$ = the binary part of $\mathbf{P}$, if defined
$R^{bs}_{\mathbf{P}} = \{\langle x,y\rangle : \{x,y\} \in [\![\mathbf{P}]\!]^C\}$ = the symmetric binary predicate based on the collective part of $\mathbf{P}$, if defined

An important feature of this system is that it does not presuppose any logical connection between the "B-part" and the "C-part" of protopredicates of type bc. For instance, nothing in the system so far forces the protopredicate denotation in (28) to include any of the pairs $\langle \mathrm{E}, \mathrm{F}\rangle$ and $\langle \mathrm{F}, \mathrm{E}\rangle$ when it includes the doubleton $\{\mathrm{E}, \mathrm{F}\}$. This means that nothing rules out situations in which *E&F hugged* is modelled as true whereas *E hugged F* or *F hugged E* is modelled as false. This is an intentional architectural decision, which is supported by the observations of Winter et al. (2016), showing the lack of logical relations between collective *hug* and binary *hug*. Any restrictions on protopredicates on top of the ones that result from their type are assumed to follow from specific features of the concepts they describe. Indeed, for two people to be considered "hugging," it might look plausible to assume that each of them is hugging the other one, as virtually all works on the topic have assumed (Dimitriadis 2008, Siloni 2012). However, as Winter et al. (2016) show, it would be too strong to require that each of the two people in a "collective hug" is hugging the other. The maximum we can require with respect to a sentence like *E&F hugged* is that one of the participants hugged the other, whereas the other collaborated in some way or another. Thus, if $\mathbf{hug}^{bc}$ includes the doubleton

$\{\mathrm{E},\mathrm{F}\}$, we should require that it also includes the pair $\langle \mathrm{E},\mathrm{F}\rangle$ or the pair $\langle \mathrm{F},\mathrm{E}\rangle$, but not necessarily both pairs. Similar remark holds for the protopredicate **collide**^{bc}: the sentence *E&F collided* may be truthfully asserted when only one among E and F *collided with* the other. Thus, we do not require both pairs $\langle \mathrm{E},\mathrm{F}\rangle$ and $\langle \mathrm{F},\mathrm{E}\rangle$ to be included in the protopredicate **collide**^{bc} in models where the doubleton $\{\mathrm{E},\mathrm{F}\}$ is.

By contrast, with a protopredicate like **fall in love**, when *E&F fell in love* is truthfully asserted under its collective reading, it is quite plausible to require that each of the participants fell in love with the other. Such differences between the pseudo-reciprocal predicates *hug* or *collide* vs. *fall in love* are not encoded in the types of their protopredicates, which are bc in all three cases. In the proposed system, any semantic connections between the collective entry and the binary entry of such verbs must emanate from properties of the underlying concepts, and not from any grammatical mechanism like the type of protopredicates we assign to them.

We have now formally specifies types of protopredicates and the restrictions that these types put on predicate denotations in natural language, using three methods for deriving these denotations (see (30)). With this formal system, we can establish that the Reciprocity-Symmetry Generalization in (15) follows as a corollary. To do that, we restate the RSG as the following property of the system we have defined.

(31) **Reciprocity-Symmetry Generalization (RSG, formal):** Let $\mathbf{P}$ be a protopredicate of type c or bc, with P the corresponding unary-collective predicate and R a corresponding symmetric predicate, s.t. $P=\mathbf{P}^{uc}$, and $R=R^{bns}_{\mathbf{P}}$ or $R=R^{bs}_{\mathbf{P}}$. The following conditions are equivalent:
  - (i) In every model, $[\![R]\!]$ is a symmetric relation.
  - (ii) In every model, $\{x,y\}\in[\![P]\!]$ iff $\langle x,y\rangle\in[\![R]\!]$ and $\langle y,x\rangle\in[\![R]\!]$.

Proof: For simplicity, we abbreviate $R^{bns}=R^{bns}_{\mathbf{P}}$ and $R^{bs}=R^{bs}_{\mathbf{P}}$. There are two cases to consider:

1. $\mathbf{P}$ is of type c. In this case $R=R^{bs}$ by definition, since R^{bns} is undefined. And any R^{bs} satisfies (i) and (ii) by definition.
2. $\mathbf{P}$ is of type bc. If $R=R^{bs}$, then again, (i) and (ii) are both satisfied in every model. Otherwise $R=R^{bns}$. In this case neither (i) nor (ii)

holds, e.g., as in the following two counter-models. First, a model where $[\![\mathbf{P}^{bc}]\!] = \{\langle c, d\rangle\}$ makes $[\![R^{bns}]\!]$ non-symmetric, hence in such a model (i) is false. Second, a model where $[\![\mathbf{P}^{bc}]\!] = \{\langle c, d\rangle, \langle d, c\rangle\}$ derives $[\![R^{bns}]\!] = \{\langle c, d\rangle, \langle d, c\rangle\}$ and $[\![P^{uc}]\!] = \emptyset$, hence in such a model (ii) in false.

We conclude that (i) and (ii) are equivalent. Thus, the RSG is supported by the system of protopredicates that we have defined. Specifically, in this system, denotations of artificial predicates like *Xhug* and *Xtalk* in (16) and (17) above cannot be derived:

1. Suppose for contradiction that a unary-collective predicate *Xhug* had the meaning "hug each other, but not necessarily at the same time." The transitive verb *hug* in English is not symmetric. Thus, for the hypothetical collective predicate *Xhug* and the transitive verb *hug* to be derived from the same protopredicate **P**, that protopredicate would have to be of type bc (rather than c). Accordingly, in any model, we would have $[\![Xhug]\!] = [\![\mathbf{P}^{bc}]\!]^C$. The type bc for **P** would allow models in which $\mathbf{P}^{bc} = \{\langle \mathrm{A}, \mathrm{B}\rangle, \{\mathrm{A}, \mathrm{B}\}\}$. Any such model would support the sentence *A hugged B* and *A&B Xhugged* but not the sentence *B hugged A*, in contradiction to the definition of *Xhug*.
2. Suppose for contradiction that a binary predicate *Xtalk* had the meaning "$\lambda x.\lambda y.$ x talks to y and y talks to x, without necessarily listening." Consider a situation S (e.g., as in footnote 5) where both *A talks to B* and *B talks to A* are judged true, but the sentence *A&B talked* is judged false. In such a situation, the sentence *A Xtalked B* would have to be judged true by the hypothetical definition of *Xtalk*. This means that the collective intransitive verb *talk* and the hypothetical transitive verb *Xtalk* would not show a plainR alternation, which rules out the possibility that both predicates are derived from the collective part $[\![\mathbf{P}]\!]^C$ of the same protopredicate. The other possibility is that **P** is of type bc and $[\![Xtalk]\!] = [\![\mathbf{P}^{bc}]\!]^B$. But such a possibility would allow models in which $[\![Xtalk]\!]$ is a non-symmetric binary relation, in contradiction to the hypothetical definition of *Xtalk*.

A sophisticated question here would be to ask why some bc protopredicates should not still be restricted by additional meaning postulates, which might create plainR or symmetry effects that do not follow from the type system. The current approach, and the proof above, rely on the assumption that such meaning postulates are not available. Since languages are assumed to own a type system that encodes the conceptual property of "collectivity" by the label c, they are assumed not to encode plainR or symmetry by predicate-specific meaning postulates.

6 Some Outstanding Issues

See Winter 2016 for some further general issues:

1. Sets with more than two members, and Irreducible Collectivity.
2. Plain reciprocity and comitative prepositions.
3. Predicates, protopredicates, concepts, and polysemy.
4. The RSG as a language universal.

For a recent experimental work on pseudo-reciprocals that supports the current proposal, see Winter et al. 2016.

7 Conclusion

The complex relations between symmetry and lexical reciprocity have been analyzed in detail, and given rise to a novel foundational observation, the Reciprocity-Symmetry Generalization. The semantic analysis of the RSG motivates protopredicates as a lexical engine that formally explains reciprocal alternations, at the interface between mental concepts and lexically interpreted forms.

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Mandarin Particle *dou*: A Pre-exhaustification Exhaustifier

Yimei Xiang

Abstract This paper provides a uniform semantics to capture various functions of Mandarin particle *dou*, including the quantifier-distributor use, the free choice item (FCI) licenser use, and the scalar marker use. I argue that *dou* is a special exhaustifier: it triggers an additive presupposition, operates on sub-alternatives, and has a pre-exhaustification effect.

Keywords Mandarin · *dou* · exhaustification · quantification · free choice · scalar · Alternative Semantics

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1 Introduction

The Mandarin particle *dou* has various uses. Descriptively speaking, it can be used as a universal quantifier-distributor, a free choice item (FCI) licenser, a scalar marker, and so on.

First, in a basic declarative sentence, the particle *dou*, similar to English *all*, is associated with a preceding nominal expression and universally quantifies and distributes over the subparts of the item denoted by this expression, as exemplified in (1). Here and throughout the paper, I use [·] to enclose the item associated with *dou*.

(1) a. [Tamen] **dou** dao -le.
they DOU arrive -ASP
'They all arrived.'

b. [Tamen] **dou** ba naxie wenti da dui -le.
they DOU BA those question answer correct -ASP
'They all correctly answered these questions.'

c. Tamen ba [naxie wenti] **dou** da dui -le.
they BA those question DOU answer correct -ASP
'They correctly answered all of these questions.'

Moreover, under the quantifier-distributor use, *dou* brings up three more semantic consequences in addition to universal quantification, namely, a "maximality requirement," a "distributivity requirement," and a "plurality requirement." The "maximality requirement" means that *dou* forces the predicate denoted by the remnant VP to apply to the maximal element in the extension of the associated item (Xiang 2008). For instance, imagine that a large group of children, with one or two exceptions, went to the park. Then (2) can be judged as true only when *dou* is absent.

(2) [Haizimen] (#**dou**) qu -le gongyuan.
children DOU go -PERF park
'The children (#all) went to the park.'

The "distributivity requirement" means that if a sentence admits both collective and atomic/nonatomic distributive readings, applying *dou* to this sentence blocks the collective reading (Lin 1998). For instance, (3a) is infelicitous if John and Mary married each other, and (3b) is infelicitous if the considered individuals only participated in one house-buying event.

(3) a. [Yuehan he Mali] **dou** jiehun -le.
John and Mary DOU get-married -ASP
'John and Mary each got married.'
b. [Tamen] **dou** mai -le fangzi.
they DOU buy -PERF house
'They all bought houses.' (#collective)

The "plurality requirement" says that the item associated with *dou* must take a non-atomic interpretation. If the prejacent sentence of *dou* has no overt non-atomic term, *dou* needs to be associated with a covert non-atomic item. For example, in (4), since the spelled-out part of prejacent sentence has no non-singular term, *dou* is associated with a covert term such as *zhe-ji-ci* 'these times'.

(4) Yuehan [(zhe-ji-ci)] **dou** qu de Beijing.
John this-several-time DOU go DE Beijing
'For all the times, the place that John went to was Beijing.'

Second, as a well-known fact, *dou* can license a preverbal *wh*-item as a universal free choice item (FCI), as exemplified in (5). Moreover, I observe that *dou* in company with a possibility modal can license the universal FCI use of a preverbal disjunction, as shown in (6a). In particular, if the possibility modal *keyi* 'can' is dropped or replaced with a necessity modal *bixu* 'must', the presence of *dou* makes the sentence ungrammatical. For example, (6a) and (6c) are grammatical only in absence of *dou*, admitting only disjunctive interpretations.

(5) a. [Shui] *(**dou**) he -guo jiu.
who DOU drink -EXP alcohol
'Anyone/everyone has had alcohol.'

b. [Na-ge nanhai] *(**dou**) he -guo hejiu.
which-CL boy DOU drink -EXP alcohol
'Any/Every boy has had alcohol.'

(6) a. [Yuehan huozhe Mali] (**dou**) keyi jiao hanyu.
John or Mary DOU can teach Chinese
Without *dou*: 'Either John or Mary can teach Chinese.'
With *dou*: 'Both John and Mary can teach Chinese.'

b. [Yuehan huozhe Mali] (***dou**) jiao hanyu.
John or Mary DOU teach Chinese

c. [Yuehan huozhe Mali] (***dou**) bixu jiao hanyu.
John or Mary DOU must teach Chinese

Third, when associated with a scalar item, *dou* implies that the prejacent sentence (namely, the sentence embedded under *dou*) ranks relatively high in the considered scale. When *dou* has this use, its associated item can stay insitu but must be focus-marked. For example, in (7a), *dou* is associated with the numeral phrase *wu dian* 'five o'clock', and the alternatives are ranked in chronological order.[1,2]

(7) a. **Dou** [WU$_F$-dian] -le.
DOU five-o'clock -ASP
'It is five o'clock.' ⇝ Being five o'clock is a bit late.

[1] Stressed items are capitalized, focused items are marked with a subscript '$_F$'.
[2] '⇝ p' means that the Mandarin example implies p.

b. Ta **dou** lai -guo zher [LIANG$_F$-ci] -le.
he DOU come -EXP here two-time -ASP.
'He has been here twice.' ⇝ Being here twice is a lot.

The [*lian* Foc *dou* . . .] construction is a special case where *dou* functions as a scalar marker. A sentence taking a [*lian* Foc *dou* . . .] form has an *even*-like interpretation; it implicates that the prejacent proposition is less likely to be true than (most of) the contextually relevant alternatives.

(8) (Lian) [duizhang]$_F$ **dou** chi dao -le.
LIAN team-leader DOU late arrive -ASP
'Even [the team leader]$_F$ arrived late.'

In particular, 'one-CL-NP' can be licensed as a minimizer at the focus position of the [*lian* Foc *dou* NEG . . .] construction, as shown in (9a). Notice that the post-*dou* negation is not always needed, as seen in (9b).

(9) a. Yuehan (lian) [YI$_F$-ge ren] *(**dou**) *(mei) qing.
John LIAN one-CL person DOU NEG invite
'John didn't invite even one person.'
b. Yuehan (lian) [YI$_F$-fen qian] *(**dou**) (mei) yao.
John LIAN one-cent money DOU NEG request
Without negation: 'John doesn't want any money.'
With negation: 'Even if it is just one cent, John wants it.'

If a sentence has multiple items that are eligible to be associated with *dou*, the function of *dou* and the association relation can be disambiguated by stress. In (10a), where the prejacent of *dou* has no stressed item, *dou* functions as a quantifier and is associated with the preceding plural term *tamen* 'they', while in (10b) and (10c), *dou* functions as a scalar marker and is associated with the stressed item.

(10) a. [Tamen] **DOU**/**dou** lai -guo liang-ci -le.
they DOU/DOU come -EXP two-time -ASP
'They ALL have been here twice.'
b. Tamen **dou** lai -guo [LIANG$_F$-ci] -le.
they DOU come -EXP two-time -ASP
'They've been here twice.' ⇝ Being here twice is a lot.

c. (Lian) [TAMEN]$_F$ **dou** lai -guo liang-ci -le.
LIAN they DOU come -EXP two-time -ASP
'Even THEY have been here twice.'

The goal of this paper is to provide a uniform semantics of *dou* to account for its seemingly diverse functions. I propose that *dou* is a special exhaustifier that operates on *sub-alternatives* and has a *pre-exhaustification effect*. The basic idea can be roughly described as follows. Assume that a *dou*-sentence is of the form "*dou*(ϕ_a)" where ϕ and a correspond to the prejacent sentence and the item contained within ϕ that is associated with *dou*, respectively. The meaning of "*dou*(ϕ_a)" is roughly 'ϕ_a and not only ϕ_b', where b' can be a proper subpart of a', a weaker scale-mate of a', and so on.[3] For example, "[A and B] dou came" means 'A and B came, not only A came, and not only B came'; "it's dou [five] o'clock" means 'it's 5 o'clock, not just 4, not just 3, ...'.

The rest of this paper is organized as follows. Section 2 will review two representative theories of the semantics of *dou*, namely, the distributor approach (Lin 1998) and the maximality operator approach (Giannakidou & Cheng 2008, Xiang 2008). Section 3 will define *dou* as a special exhaustifier and compare it with the canonical exhaustifier *only*. Section 4 will discuss the universal quantifier use of *dou*. I will show that the so called "distributivity requirement" and "plurality requirement" are both illusions, and that the facts usually thought to be related to these two requirements result from the additive presupposition of *dou*. Section 5 and 6 will be centered on the FCI-licenser use and the scalar marker use, respectively.

2 Previous Studies

There are numerous studies on the syntax and semantics of *dou*. Earlier approaches treat *dou* as an adverb with universal quantification power (Lee 1986, Cheng 1995, among others). Portner (2002) analyzes the scalar marker use of *dou* in a way similar to the inherent scalar semantics of the English focus sensitive particle *even*. Hole (2004) treats *dou* as a universal quantifier over the domain of alternatives. This section will review two more recent representative studies on the semantics of *dou*, one is the

[3]For any syntactic expression a, a' stands for the semantic value of a.

distributor approach by Lin (1996), and the other is the maximality operator approach along the lines of Giannakidou & Cheng (2006) and Xiang (2008).

2.1 The Distributor Approach

Lin (1996, 1998) provides the first extensive treatment of the semantics of *dou*. He proposes that *dou* is an overt counterpart of the generalized distributor D in the sense of Schwarzschild (1996). Unlike the regular distributor *each* which distributes over an atomic domain, the generalized D-operator distributes over the cover of the nominal phrase associated with *dou*. A cover of an individual x is a set of subparts of x, as defined in (11) and exemplified in (12). Its value is determined by both linguistic and non-linguistic factors.

(11) $Cov(\alpha, x)$ (read as "α is a cover of x") iff

a. α is a set of subparts of x;

b. every subpart of x is a subpart of some member in α.

(12) Possible covers of $a \oplus b \oplus c$ and corresponding readings:

$$\begin{array}{ll} \{a, b, c\} & \text{(atomic distributive)} \\ \left.\begin{array}{c} \{a \oplus b, c\} \\ \{a \oplus b, b \oplus c\} \\ \ldots \end{array}\right\} & \text{(nonatomic distributive)} \\ \{a \oplus b \oplus c\} & \text{(collective)} \end{array}$$

The semantics of *dou* is thus schematized as follows:

(13) $[\![dou]\!](P, x)$ is true iff
$D(\alpha)(P) = 1$, where $Cov(\alpha, x)$ iff
$\forall y \in \alpha[P(y) = 1]$, where $Cov(\alpha, x)$
(Given some contextually determined variable α such that α is a cover of x, every member of α is P.)

The distributor approach only considers the quantifier use of *dou*. It is unclear how this approach can be extended to the other uses, such as the FCI-licenser use and the scalar marker use. Moreover, even for the quantifier use, this approach faces the following challenges.

First, *dou* evokes a distributivity requirement, but the generalized *D*-distributor does not. For instance, as seen in (3b) and repeated below, the presence of *dou* eliminates the collective reading of the prejacent sentence. As Xiang (2008) argues, if *dou* were a generalized distributor, it should be compatible with a single cover reading (viz., the collective reading): there can be a discourse under which the cover of *tamen* 'they' denotes a singleton set like $\{a \oplus b \oplus c\}$; distributing over this singleton set yields a collective reading.

(14) [Tamen] **dou** mai -le fangzi.
they DOU buy -PERF house
'They **dou** bought houses.' (#collective)

Second, unlike English distributors like *each* and *all*,[4] *dou* can be associated with a distributive expression such as NP-*gezi* 'NP each'.[5]

(15) a. They each (*each/*all) has some advantages.
b. [Tamen gezi] **dou** you yixie youdian.
They each DOU have some advantage
'They each **dou** has some advantages.'

2.2 The Maximality Operator Analysis

Another popular approach, initiated by Giannakidou & Cheng (2006) and extended by Xiang (2008), is to treat *dou* as a presuppositional maximality operator. Briefly speaking, this approach proposes that *dou* operates on

[4]Champollion (2015) argues that *all* is a distributor that distributes down to subgroups, while that *each* distributes all the way down to atoms.

[5]Similar arguments have been reached in previous studies (Cheng 2009, among others), but they are mostly based on the fact that *dou* can be associated with the distributive quantificational phrase *mei*-CL-NP 'every NP', as exemplified in (i). This fact, however, cannot knock down the distributor approach for the quantifier use of *dou*: observe in (i) that stress falls on the distributive phrase *mei*-CL-NP, not the particle *dou*; therefore, here *dou* functions as a scalar marker, not a quantifier.

(i) a. [MEI-ge ren] **dou** you youdian.
every-CL person DOU have advantage
'Everyone **dou** has some advantages.'
b. ??[Mei-ge ren] **DOU** you youdian.
every-CL person DOU have advantage

a non-singleton cover of the associated item, returns the maximal plural element in this cover, and presupposes the existence of this maximal plural element. I schematize this idea as follows:

(16) Let $Cov(\alpha, x) = 1$, then
$$[\![dou]\!](x) = |\alpha| > 1 \wedge \exists y \in \alpha[\neg Atom(y) \wedge \forall z \in \alpha[z \leq y]].$$
$$\iota y \in \alpha[\neg Atom(y) \wedge \forall z \in \alpha[z \leq y]].$$
($[\![dou]\!](x)$ is defined iff the cover of x is non-singleton and has a unique non-atomic maximal element; when defined, the reference of $[\![dou]\!](x)$ is this maximal element.)

This approach is close to the standard treatment of the definite determiner *the* (Sharvy 1980, Link 1983): *the* picks out the unique maximal element in the extension of its NP complement and presupposes the existence of this maximal element.

This approach is superior to the distributor approach in two respects: first, it captures the maximality requirement; and second, it can be extended to the scalar use of *dou* (see Xiang 2008). Nevertheless, this approach still faces several conceptual or empirical problems.

First, the plurality requirement comes as a stipulation on the presupposition of *dou*: *dou* presupposes that the selected maximal element is non-atomic. It is unclear why this is so, because the definite article *the* does not trigger such a plural presupposition. Moreover, as we will see in section 4.3, this plural presupposition is neither sufficient nor necessary in dealing with the relevant facts.

Second, this approach predicts no distributivity effect at all. Under this approach, "[X] **dou** did f" only asserts that 'the maximal element in the cover of X did f', not that 'each element in the cover of X did f'. For instance in (14), if the cover of *tamen* 'they' is $\{a \oplus b, a \oplus b \oplus c\}$, the predicted assertion is simply '$a \oplus b \oplus c$ bought houses,' which says nothing as to whether $a \oplus b$ bought houses.

3 Defining *dou* as a Special Exhaustifier

This section will start with the semantics of the canonical exhaustifier *only*, and then define Mandarin particle *dou* as a special exhaustifier: *dou* is a pre-exhaustification exhaustifier that operates on sub-alternatives.

3.1 Canonical Exhaustifier *only*

The exclusive particle *only* is a canonical exhaustifier. Using Alternative Semantics for focus (Rooth 1985, 1992, 1996), we can summarize the standard treatment of the semantics of *only* in two parts. First, a focused element is associated with a set of focus alternatives. This alternative set grows point-wise (Hamblin 1973), as recursively defined in (17), adopted from Chierchia (2013:138).

(17) a. Basic Clause: for any lexical entry α, $Alt(\alpha) =$
  (i) $\{[\![\alpha]\!]\}$ if α is lexical and does not belong to a scale;
  (ii) $\{[\![\alpha_1]\!], \ldots, [\![\alpha_n]\!]\}$
  if α is lexical and part of a scale $\langle[\![\alpha_1]\!], \ldots, [\![\alpha_n]\!]\rangle$.

b. Recursive Clause:
$Alt(\beta(\alpha)) = \{b(a) : b \in Alt(\beta), a \in Alt(\alpha)\}$

Second, the exclusive particle *only* presupposes the truth of its prejacent proposition (Horn 1969) and asserts an exhaustivity condition. This condition says that all the excludable alternatives of the prejacent clause are false. For any proposition p, an alternative of p is excludable as long as it is not entailed by p.

(18) a. $[\![only]\!](p) = \lambda w[q(w) = 1.\forall q \in Excl(p)[q(w) = 0]]$
(To be revised in (20))

b. $Excl(p) = \{q : q \in Alt(p) \wedge p \nsubseteq q\}$

In addition to the prejacent presupposition, I argue that *only* also triggers an additive presupposition, namely, that the prejacent has at least one excludable alternative. In (19), *only* has a restricted exhaustification domain, namely, {*I will invite John*, *I will invite Mary*, *I will invite John and Mary*}. Contrary to the case of (19a), (19b) is infelicitous because the prejacent *I will invite both John and Mary* is the strongest one among the alternatives and has no excludable alternative. As Martin Hackl (pers. comm.) points out, the additive presupposition of *only* can be reduced to a more general economy condition that an overt operator cannot be applied vacuously. For sake of comparison, observe that (19c) is felicitous, which is because covert exhaustification is free from the economy condition and so does not trigger an additive presupposition.

(19) Which of John and Mary will you invite?
   a. Only JOHN$_F$, (not Mary / not both).
   b. #Only BOTH$_F$.
   c. BOTH$_F$.

In sum, I schematize the semantics of *only* as follows: it presupposes the truth of its prejacent and the existence of an excludable alternative; it negates each excludable alternative.

(20) $[\![only]\!](p) = \lambda w.[p(w) = 1 \wedge \exists q \in Excl(p)].$
$\lambda w.\forall q \in Excl(p)[q(w) = 0]$ (Final version)
   a. Prejacent presupposition: p
   b. Additive presupposition: $\exists q \in Excl(p)$
   c. Assertion: $\lambda w.\forall q \in Excl(p)[q(w) = 0]$

3.2 Special Exhaustifier *dou*

I define *dou* as a pre-exhaustification exhaustifier over sub-alternatives, as schematized in (21): it presupposes an additive inference; it affirms the prejacent and negates the exhaustification of each sub-alternative.

(21) $[\![dou]\!](p) = \exists q \in Sub(p).$
$\lambda w[p(w) = 1 \wedge \forall q \in Sub(p)[O(q)(w) = 0]]$

The additive presupposition is motivated by the economy condition, just as we saw with the canonical exhaustifier *only*. The anti-exhaustification inference asserted by *dou* differs from that asserted by *only* in two respects. First, *only* operates on excludable alternatives, but *dou* operates on *sub-alternatives*. For now we can understand sub-alternatives as weaker alternatives, or equivalently, the alternatives that are not excludable (viz., not entailed by the prejacent) and are distinct from the prejacent, as schematized in (22). The sign '−' stands for set subtraction. A revision will be made in section 5.

(22) $Sub(p) = \{q : q \in Alt(p) \wedge p \subsetneq q\}$ (To be revised in (44c))
$= (Alt(p) - Excl(p)) - \{p\}$

Second, *dou* has a pre-exhaustification effect: it negates the "exhaustification" of each sub-alternative. The pre-exhaustification effect is realized by applying an *O*-operator to each sub-alternative.[6] The *O*-operator is a covert counterpart of the exclusive particle *only*, coined by the grammatical view of scalar implicatures (Fox 2007, Chierchia et al. 2012, Fox & Spector to appear, among others). This *O*-operator affirms the prejacent and negates all the excludable alternatives of the prejacent.

(23) $O(p) = \lambda w[p(w) = 1 \wedge \forall q \in Excl(p)[q(w) = 0]]$
(Chierchia et al. 2012)

Consider (24) for a simple illustration of the present definition. The prejacent proposition and its alternative set are (24a) and (24b), respectively. Only the two alternatives in (24c) are asymmetrically entailed by the prejacent, which are therefore the sub-alternatives. The use of *dou* affirms the prejacent and negates the exhaustification of each sub-alternative, as in (24d), yielding the following inference: John and Mary arrived, not only John arrived, and not only Mary arrived. The *anti-exhaustification* inference given by the *not only*-clauses is entailed by the prejacent and adds nothing new to the truth conditions.[7]

[6]In section 6, we will see other options to derive the pre-exhaustification effect. For instance, when *dou* is used as a scalar marker, the pre-exhaustification effect is realized by applying a scalar exhaustifier ($\approx$ *just*) to the sub-alternatives.

[7]One might wonder why *dou* is used even though it does not change the truth conditions. Such uses are observed cross-linguistically. For instance, in (i), the distributor *both* adds nothing to the truth conditions.

(i) John and Mary *both* arrived.

One possibility, raised by the audience at LAGB 2015, is that *dou* and *both* are used for the sake of contrasting with non-maximal operators like *only part of* or *only one of*. If this is the case, the question under discussion for (24) and (i) would be 'is it the case that John and Mary both arrived or that only one of them arrived?' This idea is supported by the oddness of using *both*/*dou* in the following conversation:

(ii) Q: "Who arrived?"
A: "John and Mary #(*both*/*dou*) arrived."

Using *dou* makes the answer incongruent with the explicit question: if *dou* is present, the answer has an alternative "only John or only Mary arrived," which is not in the Hamblin set of the explicit question (viz., $\{x \text{ arrived}: x \in D_e\}$).

This idea also explains the maximality requirement of *dou*. Here let me just sketch out

(24) [John and Mary] **dou** arrived.

a. $p = A(j \oplus m)$
b. $Alt(p) = \{A(x) : x \in D_e\}$
c. $Sub(p) = \{A(j), A(m)\}$
d. $[\![dou]\!](p) = A(j \oplus m) \wedge \neg O[A(j)] \wedge \neg O[A(m)]$

4 The Universal Quantifier Use

Recall that *dou* evokes three requirements when used as a universal quantifier: (i) the "maximality requirement," namely, that *dou* forces maximality with respect to the domain denoted by the associated item; (ii) the "distributivity requirement," namely, that the prejacent sentence cannot take a collective reading; (iii) the "plurality requirement," namely, that the item associated with *dou* must take a non-atomic interpretation. This section will focus on the latter two requirements. (See footnote 7 for a rough idea on the maximality requirement.) I will argue that these two requirements are both illusions. Moreover, I will argue that all the facts that are thought to result from these two requirements actually result from the additive presupposition of *dou*.

4.1 Explaining the "Distributivity Requirement"

To generate sub-alternatives and satisfy the additive presupposition of *dou*, the prejacent of *dou* needs to be monotonic with respect to the item associated with *dou*,[8] which therefore gives rise to the "distributivity re-

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this idea informally: the assertion of the *dou*-sentence (iii) is identical to that of (iiia), which is tolerant of non-maximality; but (iii) also implicates the anti-non-maximality inference (iiib), giving rise to a maximality requirement.

(iii) (Scenario: The children, with only one or two exceptions, went to the park.)

[Haizimen] (#**dou**) qu -le gongyuan.
children DOU go -PERF park
'The children (#all) went to the park.'

a. The children went to the park.
b. Not [only part of the children went to the park.]

[8]If α is of type δ and A is a constituent that contains α, then A is monotonic with respect to α iff the function $\lambda x.[\![A[\alpha/v_\delta]]\!]^{g[v_\delta \to x]}$ is monotonic (adapted from Gajewski 2007). Here $A[\alpha/v]$ stands for the result of replacing α with v in A.

quirement." For instance, (25) rejects a collective reading because under this reading the prejacent proposition of *dou* is non-monotonic with respect to the subject position and hence has no sub-alternative, as shown in (25a). In contrast, when taking an atomic or a non-atomic distributive reading, the prejacent of *dou* is monotonic with respect to the subject position and does generate some sub-alternatives, as shown in (25b) and (25c).[9]

(25) [*abc*] **dou** bought houses.

a. *Collective #*

(i) *abc* together bought houses.
$\not\Rightarrow$ *ab* together bought houses.

(ii) $Sub(abc\ together\ bought\ houses) = \emptyset$

b. *Atomic distributive* $\surd$

(i) *abc* each bought houses. $\Rightarrow$ *ab* each bought houses.

(ii) $Sub(each(x)(BH)) = \{each(x)(BH) : x \lneq abc\}$

c. *Nonatomic distributive* $\surd$

(i) members of C_{abc} each bought houses.
$\Rightarrow$ members of X each bought houses ($X \subsetneq C_{abc}$)

(ii) $Sub(D(C_{abc})(BH)) = \{D(X)(BH) : X \subsetneq C_{abc}\}$

Hence, *dou* itself is not a distributor; but in certain cases, the additive presupposition of *dou* evokes the use of a distributor (a covert *each* or a covert generalized distributor). We can now easily explain why *dou* can be associated with a distributive expression NP-*gezi* 'NP-each': the presence of the distributor *gezi* 'each' is actually required for the sake of satisfying the additive presupposition of *dou*; if *gezi* is not overtly used, a covert distributor is still present in the logical form.

(26) [Tamen gezi] **dou** you yixie youdian.
they each DOU have some advantage
'They each **dou** has some advantages .'

Moreover, *dou* can be applied to a collective statement as long as this statement satisfies the monotonicity requirement, namely, is monotonic

[9] C_{abc} in (25c) stands for a free variable that is a cover of *abc*.

with respect to the item associated with *dou*. For instance, *dou* is compatible with monotonic collective predicates (e.g., *shi pengyou* 'be friends', *jihe* 'gather', *jianmian* 'meet'), as shown in (27). Consider, for instance, (27a). Let *tamen* 'they' denote three individuals *abc*. The set of sub-alternative sets is {*ab are friends*, *bc are friends*, *ac are friends*}; applying *dou* yields the following inference: *abc* are friends, not only *ab* are friends, not only *bc* are friends, and not only *ac* are friends.

(27) a. [Tamen] (**dou**) shi pengyou.
they DOU be friends
'They are (all) friends.'
b. [Tamen] (**dou**) zai dating jihe -le.
they DOU at hallway gather -ASP
'They (all) gathered in the hallway.'
c. [Tamen] (**dou**) jian-guo-mian -le.
They DOU see-EXP-face -ASP
'They (all) have met.'

By comparison, *dou* cannot be applied to a collective statement that does not satisfy the monotonicity requirement, as shown in (28).

(28) [Tamen] (***dou**) zucheng -le lia er-ren-zu.
they DOU form -ASP two two-person-group
'They (*all) formed two pairs.'

We have to distinguish the case in (28) from the following ones, where the prejacent sentences actually admit non-collective (viz., non-atomic distributive) readings and thus satisfy the monotonicity requirement.

(29) [Tamen] **dou** zucheng -le er-ren-zu.
they DOU form -ASP two-person-group
'They all formed pairs.'

(30) [Women he tamen] **dou** zucheng -le lia er-ren-zu.
we and they DOU form -ASP two two-person-group
'We formed two pairs, and they formed two pairs.'

In (29), the extension of the predicate *formed pairs* (FP) is closed under sum, just like any plural term: $\mathrm{FP}(a \oplus b) \wedge \mathrm{FP}(c \oplus d) \Rightarrow \mathrm{FP}(a \oplus b \oplus c \oplus$

d) (see Kratzer 2008 for the question of pluralizing verbal predicates); hence the prejacent sentence admits a covered/cumulative reading. In (30), although the predicate *formed two pairs* (F2P) is non-monotonic, the subject *we and they* can be interpreted as a generalized conjunction, each conjunct of which yields a sub-alternative. A schematized derivation for the sub-alternatives in (30) is given in (31).

(31) a. $[\![\textit{we and they}]\!] = \lambda P_{et}[P(we) \wedge P(they)]$
b. $[\![\textit{we and they F2P}]\!] = F2P(we) \wedge F2P(they)$
c. $Sub(\textit{we and they F2P}) = \{F2P(we), F2P(they)\}$

4.2 Explaining the "Plurality Requirement"

I argue that the "plurality requirement" of *dou* is illusive, and that the related facts all result from the additive presupposition of *dou*.

First, the plurality requirement is unnecessary: *dou* can be associated with an atomic item as long as the predicate denoted by the remnant VP is predicate.

(32) P is divisive iff $\forall x[P(x) = 1 \rightarrow \forall y \leq x[P(y) = 1]]$
(A predicate is divisive iff whenever it holds of something, it also holds of each of its subparts.)

For instance, in (33a), the associated item *that apple* takes only an atomic interpretation; with a divisive predicate $\lambda x.\, \textit{John ate } x$, the prejacent sentence of *dou* has sub-alternatives, as schematized in (34a), which therefore supports the additive presupposition of *dou*. In contrast, in (33b), the predicate $\lambda x.\, \textit{John ate half of } x$ is not divisive and hence is incompatible with the use of *dou*.

(33) a. Yuehan ba [na-ge pingguo] (**dou**) chi -le.
John BA that-CL apple DOU eat -PERF
'John ate that apple.'
b. Yuehan ba [na-ge pingguo] (***dou**) chi -le yi-ban.
John BA that-CL apple DOU eat -PERF one-half
Intended: 'John ate half of that apple.'

(34) a. 'John ate that apple.' ⇒ 'John ate x.' ($x \lneq$ that apple)
$Sub(\textit{John ate that apple}) = \{\textit{John ate } x \colon x \lneq \textit{that apple}\}$

b. 'John ate half of that apple.'
$\not\Rightarrow$ 'John ate half of x.' ($x \lneq$ that apple)
$Sub(\textit{John ate half of that apple}) = \varnothing$

Second, the plurality requirement is insufficient. When followed by a monotonic collective predicate, *dou* requires its associated item to denote a group consisting of at least three members, as shown in (35).

(35) [Tamen -sa/*-lia] **dou** shi pengyou.
they -three/-two DOU be friends
'They three/*two are all friends.'

This fact is also predicted by the additive presupposition. As schematized in (36), the proper subparts of an dual-individual are atomic individuals, which, however, are undefined for the collective predicate 'be friends'. Consequently, if the item associated with *dou* in (35) denotes only a dual-individual, the prejacent of *dou* has no sub-alternative, which therefore leaves the presupposition of *dou* unsatisfied.

(36) [*ab*] (***dou**) are friends.

a. $[\![\textit{be friends}]\!] = \lambda x[\neg Atom(x).\textit{be-friends}(x)]$
b. $Sub(\textit{ab are friends}) = \varnothing$

5 The Universal FCI-licenser Use

Dou can license the universal FCI use of polarity items, *wh*-items, and preverbal disjunctions. In this section, I argue that the asserted component of *dou* converts a disjunctive/existential statement into a conjunctive/universal statement, giving rise to a free choice (FC) inference. I will also explain why the licensing of universal FCIs requires the presence of *dou*, and why the licensing of a preverbal disjunction as a universal FCI exhibits the effect of modal obviation.

5.1 Licensing Conditions of Mandarin FCIs

In Mandarin, the licensing of a universal FCI requires the presence of *dou*. For instance, in (37), the bare *wh*-word *shei* 'who' is licensed as a universal FCI only when it precedes *dou*.

(37) [Shei] *(**dou**) jiao -guo jichu hanyu.
who DOU teach -EXP intro Chinese.
'Everyone has taught Intro Chinese.'

To license the universal FCI use of a disjunction, *dou* must be present and followed by a possibility modal, as shown in (38) and (39).

(38) [Yuehan huozhe Mali] **dou** keyi/*bixu jiao jichu hanyu.
John or Mary DOU can/must teach intro Chinese
'Both John and Mary can teach Intro Chinese.'

(39) [Yuehan huozhe Mali] (***dou**) jiao -guo jichu hanyu.
John or Mary DOU teach -EXP intro Chinese
Intended: 'Both Johan and Mary have taught Intro Chinese.'

This requirement is also observed with English emphatic item *any*: as shown in (40), *any* is licensed as a universal FCI when it precedes a possibility modal, but not licensed when it appears in an episodic statement or before a necessity modal.

(40) a. *Anyone came in.
b. Anyone can/*must come in.

The licensing conditions of *na*-CL-NP 'which-NP' and *renhe*-NP 'any-NP' are less clear. Giannakidou & Cheng (2006) claim that the universal FCI uses of these items are only licensed in a pre-*dou*+$\Diamond$ position; their judgements are illustrated in (41). Nevertheless, it is difficult to do justice to the data because judgements of (41) vary greatly among native speakers.

(41) a. [Na-ge/Renhe -ren] **dou** keyi/?bixu lai.
which-CL/anywhat -person DOU can/must come
Intended: 'Everyone can/must come.'
b. ?[Na-ge/Renhe -ren] **dou** lai -guo.
which-CL/anywhat -person DOU come -ASP
Intended: 'Everyone has been here.'

Despite the variation in the judgments, the licensing conditions of universal FCIs in Mandarin can be summarized as follows. First, every universal FCI requires the presence of *dou*. Second, every universal FCI can be licensed before *dou*+$\Diamond$. Third, in absence of the possibility modal, 'which'/'any'-NP is less likely to be licensed than bare *wh*-words, but more likely to be licensed than disjunctions. For other recent studies, see Liao 2011, Cheng & Giannakidou 2013, and Chierchia & Liao 2015.

5.2 Predicting Universal FC Inferences

Wh-items are generally considered as existential indefinites; thus in (37), repeated in (42), the prejacent sentence of *dou* is a disjunction, and the sub-alternatives are the disjuncts. Applying *dou* affirms the prejacent and negates the exhaustification of each disjunct, yielding a universal FC inference. In a word, *dou* turns a disjunction into a conjunction.

(42) [Shei] *(**dou**) has taught Intro Chinese.

a. $p = f(a) \vee f(b)$

b. $Sub(p) = \{f(a), f(b)\}$

c. $[\![dou]\!](p)$
$= [f(a) \vee f(b)] \wedge \neg O f(a) \wedge \neg O f(b)$
$= [f(a) \vee f(b)] \wedge [f(a) \rightarrow f(b)] \wedge [f(b) \rightarrow f(a)]$
$= [f(a) \vee f(b)] \wedge [f(a) \leftrightarrow f(b)]$
$= f(a) \wedge f(b)$

What makes the use of *dou* mandatory in (37)? Following Liao (2011) and Chierchia & Liao (2015), I assume that the sub-alternatives associated with a Mandarin *wh*-word are obligatorily activated when this *wh*-word has a non-interrogative use, and that they must be used up via employing a c-commanding exhaustifier.[10] If *dou* is absent, these sub-alternatives would be used by a basic exhaustifier (23), repeated in (43a), which has no pre-exhaustification effect. As schematized in (43b), a basic *O*-operator affirms the prejacent disjunction and negates both disjuncts, yielding a contradiction.[11]

(43) a. $O(p) = \lambda w[p(w) \wedge \forall q \in Excl(p)[q(w) = 0]]$

b. $O(f(a) \vee f(b)) = [f(a) \vee f(b)] \wedge \neg f(a) \wedge \neg f(b) = \bot$

[10]In the case of disjunctions, sub-alternatives are simply what usually call "domain alternatives," evoked by domain widening (Krifka 1995, Lahiri 1998, Chierchia 2006).

[11]Disjunctions are free from this problem, because they do not mandatorily evoke sub-alternatives. See Chierchia 2006 for discussions on activations of alternatives.

Now, a problem arises as to the definition of sub-alternatives: in section 3, I defined sub-alternatives as weaker alternatives, namely, alternatives that are not excludable and distinct from the prejacent; but in (42) the disjuncts are semantically stronger than the disjunction.

This problem can be solved by a simple move from excludability to *innocent excludability*, a notion proposed by Fox (2007): an alternative is innocently excludable iff the inference of affirming the prejacent and negating this alternative is consistent with negating any excludable alternative. Thus, we can say that sub-alternatives are alternatives that are not *innocently excludable* and are distinct from the prejacent.

(44) a. **Excludable alternatives** (Chierchia et al. 2012)
$Excl(p) = \{q : q \in Alt(p) \wedge p \nsubseteq q\}$
(The set of alternatives that are entailed by the prejacent)

b. **Innocently excludable alternatives** (Fox 2007)
$IExcl(p) = \{q : q \in Alt(p) \wedge$
$\neg\exists q' \in Excl(p)[(\lambda w[p(w) = 1 \wedge q(w) = 0]) \subseteq q']\}$
(The set of alternatives p such that affirming p and negating q does not entail any excludable alternatives)

c. **Sub-alternatives** (Final version, cf. (22))
$Sub(p) = (Alt(p) - IExcl(p)) - \{p\}$
(The set of alternatives excluding the innocently excludable alternatives and the prejacent)

In (42), the disjuncts are not innocently excludable to the disjunction: as schematized below, affirming the disjunction and negating one of the disjuncts entail the other disjunct; in other words, affirming the disjunction and negating both disjuncts would yield a contradiction. Hence, the sub-alternatives of a disjunction are the disjuncts.

(45) $[[f(a) \vee f(b)] \wedge \neg f(a)] \Rightarrow f(b)$

Note that weaker alternatives are not innocently excludable: affirming a prejacent and negating a weaker alternative yield a contradiction, which entails any proposition. Hence, for cases where *dou* functions as a distributor, the new definition of sub-alternatives (44c) has the same consequence as the previous one in (22), which defines sub-alternatives as weaker alternatives.

A full definition of *dou* is schematized as follows:

(46) a. $[\![dou]\!](p) = \exists q \in Sub(p).$
$$\lambda w[p(w) = 1 \wedge \forall q \in Sub(p)[O(q)(w) = 0]]$$
(i) Presupposition: p has some sub-alternatives.
(ii) Assertion: p is true, while the exhaustification of each sub-alternative of p is false.

b. $Sub(p) = (Alt(p) - IExcl(p)) - \{p\}$
(The set of alternatives excluding the innocently excludable alternatives and the prejacent)

Readers who are familiar with the grammatical view of exhaustifications might find that *dou* is similar to the operation of recursive exhaustifications (abbreviated as 'O_R') proposed by Fox (2007). This operation has two major characteristics: first, exhaustification negates only alternatives that are innocently excludable; second, exhaustification is applied recursively. Using the notations in (46), I schematize the semantics of O_R as follows:[12]

(47) $$O_R(p) = \lambda w[p(w) = 1 \wedge \forall q \in Sub(p)[O(q)(w) = 0] \wedge \forall q' \in IExcl(p)[q'(w) = 0]]$$

Thus *dou* is weaker than O_R: *dou* does not negate the innocently excludable alternatives; therefore, applying *dou* to a disjunction does not generate an exclusive inference. For instance, (38) does not imply the exclusive

[12]In particular cases, the definition of O_R in (47) yields inferences different from what Fox's idea would expect: if the exhaustification of a sub-alternative is not innocently excludable, the exhaustification of this sub-alternative would not be negated by O_R under Fox's original definition. See (i) for a concrete example.

(i) (Among Andy and Billy,) only Andy came or only Billy came.

a. Prejacent: $O\phi_a \vee O\phi_b$; $Sub(O\phi_a \vee O\phi_b) = \{O\phi_a, O\phi_b\}$

b. By definition (47), applying O_R yields a contradiction:
$[O\phi_a \vee O\phi_b] \wedge \neg OO\phi_a \wedge \neg OO\phi_b = [O\phi_a \vee O\phi_b] \wedge \neg O\phi_a \wedge \neg O\phi_b = \bot$

c. By Fox's original definition, O_R would be applied vacuously:
$O_R[O\phi_a \vee O\phi_b] = O\phi_a \vee O\phi_b$

inference that only John and Mary can teach Intro Chinese.

5.3 Modal Obviation

Recall the contrast between disjunctions and bare *wh*-words with respect to the licensing conditions of their FCI uses: *dou* alone is sufficient for licensing the universal FCI use of a bare *wh*-word, but not that of a disjunction; to license this use of a disjunction, *dou* must be followed by a possibility modal. To capture this contrast, I assume that disjunctions evoke scalar implicatures, while bare *wh*-words do not (cf. Liao 2011, Chierchia & Liao 2015). Compare the following two episodic sentences. *Dou* must be present in (48a) but must be absent in (48b).

(48) a. [Shei] *(**dou**) jiao -guo jichu hanyu.
who DOU teach -EXP intro Chinese
With *dou*: 'Everyone has taught Intro Chinese.'

b. [Yuehan huozhe Mali] (***dou**) jiao -guo jichu hanyu.
John or Mary DOU teach -EXP intro Chinese
Without *dou*: 'John or Mary has taught Intro Chinese.'

In both sentences, the use of *dou* yields an FC inference that John and Mary/everyone have/has taught Intro Chinese. But in (48b), with a disjunction, the prejacent clause of *dou* also evokes the following scalar implicature, which contradicts to the FC inference: it is not the case that both John and Mary have taught Intro Chinese. Hence, *dou* cannot be used in (48b) because it yields a universal FC inference which contradicts the scalar implicature (*à la* Chierchia's (2013) explanation of the licensing condition of the FCI *any*). By contrast, in absence of *dou*, the sub-alternatives of a disjunction are not activated, and then (48b) would take a simple disjunctive reading.

A preverbal disjunction is licensed as a universal FCI when it appears before *dou*+$\Diamond$. This effect is called "modal obviation," namely, that the presence of a possibility modal eliminates the ungrammaticality. This effect is also observed with English *any*, as seen in (40).

(49) a. [Yuehan huozhe Mali] **dou** keyi jiao jichu hanyu.
John or Mary DOU can teach intro Chinese
'Both John and Mary can teach Intro Chinese.'

b. [Yuehan huozhe Mali] (***dou**) bixu jiao jichu hanyu.
John or Mary DOU must teach intro Chinese
'Both John and Mary must teach Intro Chinese.'

There have been plenty of discussions on the phenomenon of Modal Obviation involved in licensing universal FCIs. Representative works include Dayal 1998, 2013, Giannakidou 2001, Chierchia 2013, among others. This paper is not in a position to do full justice to these discussions, but just adds one more accessible story to the market.

I propose that the scalar implicature of a preverbal disjunction can be assessed within a circumstantial modal base: the modal base is restricted to the set of worlds where the scalar implicature is satisfied. For instance, (49) intuitively suggests that the speaker is only interested in cases where exactly one person teaches Intro Chinese. Assume that the property *teach Intro Chinese* denotes only three world-individual pairs, as in (50a). For instance, the pair $\langle w1, \{j\}\rangle$ is read as 'only John teaches Intro Chinese in $w1$'. The scalar implicature of the preverbal disjunction restricts the modal base M to the set of worlds where not both John and Mary teach Intro Chinese, as in (50b). Exercising *dou* yields the universal FC inferences in (50c) and (50d). Crucially, only (50c) is true with respect to M.

(50) a. $f = \{\langle w1, \{j\}\rangle, \langle w2, \{m\}\rangle, \langle w3, \{j, m\}\rangle\}$
b. $M = \{w1, w2\}$
c. $[\![dou]\!]\ [\Diamond f(j) \vee \Diamond f(m)] = \Diamond f(j) \wedge \Diamond f(m)$ True w.r.t. M
d. $[\![dou]\!]\ [\Box f(j) \vee \Box f(m)] = \Box f(j) \wedge \Box f(m)$ False w.r.t. M

Broadly speaking, there is no modal base, except the empty one, with respect to which (50d) is true; therefore necessity modals cannot obviate the contradiction between the FC inference and the scalar implicature.

If I am on the right track, as for the licensing conditions for the universal FCI uses of *na*-CL-NP and *renhe*-NP, whether a speaker accepts (41) in absence of the possibility modal is determined by whether he interprets these items with scalar implicatures.

6 Scalar Marker

When *dou* is associated with a scalar item or occurs in the focus construction [*lian* Foc *dou* ...], it functions as a scalar marker. In such a case, sub-alternatives are the alternatives ranking strictly lower than the prejacent with respect to a contextually relevant probability measure, and the pre-exhaustification effect is realized by the scalar exhaustifier JUST. In the following, I will firstly sketch out the semantics of the scalar *dou*, and then capture the *even*-like interpretation and the licensing conditions of minimizers in the [*lian* Foc/Min *dou* ...] construction.

6.1 Association with a Scalar Item

When *dou* is associated with a scalar item, the sub-alternatives are alternatives that rank lower than the prejacent proposition on the relevant scale, as schematized in (51), where $q \lneq_\mu p$ says that q ranks strictly lower than p with respect to some contextually relevant probability measure μ. $Alt_C(p)$ stands for the set of contextually relevant alternatives of p. For instance, in (52), repeated from (7a), sub-alternatives are propositions that rank lower than the prejacent in chronological order.

(51) $Sub(p) = \{q : q \in Alt_C(p) \wedge q \lneq_\mu p\}$
(The set of contextually relevant alternatives of p that rank lower than p with respect to μ)

(52) **Dou** [WU$_F$-dian] -le.
DOU five-o'clock -ASP
'It is **dou** FIVE$_F$ o'clock.'
a. $Sub(it's\ 5\ o'clock) = \{it's\ 4\ o'clock, it's\ 3\ o'clock, \ldots\}$
b. $[\![dou[it's\ 5\ o'clock]]\!]$ = 'it's 5, not just 4, not just 3, ...'

To generate sub-alternatives and satisfy the additive presupposition of *dou*, the prejacent clause of *dou* needs to rank relatively high in the relevant scale. For instance, in (53), *dou* can be associated with *many*-NP but not with *few*-NP, because the prejacent of *dou* must be relatively strong among the quantificational statements.

(53) [Duo/*Shao -shu -ren] **dou** lai -le.
many/less -amount -person DOU come -ASP
'Most/*few people **dou** came.'

Since the alternatives of (52) are ordered based on their strength in the considered scale, the pre-exhaustification effect of *dou* is realized by the scalar exhaustifier JUST. As schematized in (54), the semantics of JUST is analogous to that of the *O*-operator: JUST affirms the prejacent p and further states a scalar exhaustivity condition that there is no true alternative of p that ranks higher than p with respect to the contextually relevant measurement. Hence, when *dou* functions as a scalar marker, its semantics would be adapted to (55).

(54) $\text{JUST}(p) = \lambda w[p(w) = 1 \wedge \forall q \in Alt_C(p)[q(w) = 1 \rightarrow q \leq_\mu p]]$
(*p* is true; every contextually relevant true alternative of p ranks not higher than p with respect to μ.)

(55) $[\![dou]\!](p) = \exists q \in Sub(p).$
$\lambda w[p(w) = 1 \wedge \forall q \in Sub(p)[\text{JUST}(q)(w) = 0]]$
(p, and for any sub-alternative q, not just q; defined iff p has a sub-alternative.)

We can further simplify the assertion, because the anti-exhaustification condition provided by the *not just*-clause is entailed by the remnant prejacent condition. [Proof: If q is an alternative of p that ranks lower than p with respect to μ, then p is an alternative of p that ranks higher than q with respect to μ. Hence, if p is true, there exists a true alternative of p that ranks higher than q with respect to μ, namely, p. End of proof.]

(56) Simplify the assertion of $[\![dou]\!](p)$:
$\lambda w[p(w) = 1 \wedge \forall q \in Sub(p)[\text{JUST}(p)(w) = 0]]$
$= \lambda w[p(w) = 1 \wedge \forall q \in Sub(p) \exists q' \in Alt_C(p)[q'(w) = 1 \wedge q \gnsim_\mu q']]$
$= \lambda w[p(w) = 1 \wedge$
$\forall q \in Alt_C(p)[q \lnsim_\mu p \rightarrow \exists q' \in Alt_C(p)[q'(w) = 1 \wedge q \gnsim_\mu q']]]$
$= p$

The semantics of the scalar marker *dou* is finally defined as follows:

(57) $[\![dou]\!](p) = \exists q \in Alt_C(p)[q \lnsim_\mu p].p$
(p; defined iff there is a contextually relevant alternative of p that ranks lower than p with respect to μ.)

6.2 The [*lian* Foc *dou* . . .] Construction

In the [*lian* Foc *dou* . . .] construction, alternatives are ordered with respect to likelihood. Sub-alternatives are focus alternatives that are more likely to be true than the prejacent, as schematized in (58). This definition is a natural transition from informativity to likelihood: a proposition that is less informative (viz., weaker) is more likely to be true.[13]

(58) $Sub(p) = \{q : q \in Alt_C(p) \wedge q \gtrnsim_{\text{likely}} p\}$
(The set of contextually relevant alternatives of p that are more likely to be true than p)

For instance, in (59), alternatives are propositions of the form "x was late" where x is a relevant individual. In a context that a team leader is less likely to be late than a team member, sub-alternatives are *the team member A was late*, *the team member B was late*, etc. Thus (59) means 'the team leader was late, not just that a team member was late.'

(59) **Lian** [duizhang]$_F$ **dou** chidao -le.
LIAN team-leader DOU late -ASP
'Even the team leader was late.'

Extending the definition of *dou* to the [*lian* Foc *dou* . . .] construction, I schematize the meaning of *dou* in (60). Just like what we saw in (56), the anti-exhaustification condition is asymmetrically entailed by prejacent condition and hence is neglected in the end.

(60)
$$\begin{aligned}
&[\![dou]\!](p)\\
&= \exists q \in Sub(p).\lambda w[p(w) = 1 \wedge \forall q \in Sub(p)[\textsc{just}(p)(w) = 0]]\\
&= \exists q \in Sub(p).\lambda w[p(w) = 1 \wedge\\
&\qquad\qquad \forall q \in Sub(p) \exists q' \in Alt_C(p)[q'(w) = 1 \wedge q \gtrnsim_{\text{likely}} q']]\\
&= \exists q \in Alt_C(p)[q \gtrnsim_{\text{likely}} p].\\
&\quad \lambda w[p(w) = 1 \wedge \forall q \in Alt_C(p)[q \gtrnsim_{\text{likely}} p \rightarrow\\
&\qquad\qquad \exists q' \in Alt_C(p)[q'(w) = 1 \wedge q \gtrnsim_{\text{likely}} q']]]\\
&= \exists q \in Alt_C(p)[q \gtrnsim_{\text{likely}} p].p
\end{aligned}$$

[13] To be consistent with the general definition in (51), we can use "unlikelihood" as the probability measurement and define sub-alternatives as the ones that are less unlikely to be true than the prejacent.

(p is true; defined only if p has a contextually relevant alternative that is more likely to be true than p.)

Notice that the presupposition of the scalar marker *dou* is identical to the scalar presupposition of the additive scalar focus-sensitive operator *even*, according to the tradition initiated by Bennett (1982) and Kay (1990): the prejacent proposition is less likely to be true than at least one contextually relevant alternative.[14] Thus, it is plausible to say that the *even*-like interpretation of the [*lian* Foc *dou* ...] construction comes from the additive presupposition of *dou* (Portner 2002, Shyu 2004, Paris 1998, Liu to appear), while the particle *lian* is semantically vacuous and is present only for syntactic purposes.

6.3 Association with a Minimizer

Observe that, in licensing a minimizer, the post-*dou* negation is mandatory in (61a) but optional in (61b).

(61) a. Yuehan (lian) [YI-ge ren]$_F$ *(**dou**) *(bu) renshi.
John LIAN one-CL person DOU NEG know
'John doesn't know anyone.'

b. Yuehan (lian) [YI-fen qian]$_F$ *(**dou**) (bu) yao.
John LIAN one-cent money DOU NEG request
Without negation: 'John even doesn't want one cent.'
With negation: 'John wants it even if it is just one cent.'

I argue that the distributional pattern of the post-*dou* negation in a [*lian* MIN *dou* (NEG) ...] construction is also constrained by the additive presupposition of *dou*.

The additive presupposition of *dou* requires the prejacent not to be weakest proposition among the alternatives. In (61a), this requirement forces the minimizer *one person* to take reconstruction and gets inter-

[14]Note that this additive presupposition says nothing about the truth value of any sub-alternative, as shown in (i).

(i) **Lian** [Yuehan]$_F$ **dou** jige -le, qita-ren zenme mei -you?
LIAN John DOU pass -ASP, other-person how NEG -ASP.
'Even [John]$_F$ passed the exam, why is that the others didn't?'

preted below negation, as in (62b): without reconstruction, the prejacent would be *There is at least one person whom John didn't invite*, which is weaker than any alternatives of the form *There are at least n people whom John didn't invite* ($n > 1$); in contrast, under the LF in (62b) which involves reconstruction of *one person*, the prejacent ¬[*John invited at least one person*] is stronger than alternatives of the form ¬[*John invited at least n people*] ($n > 1$).

(62) a. ***Dou** [**one person**$_i$ NEG [John knows t_i]]
b. **Dou** [NEG [John knows **one person**]]

This reconstruction-based analysis is supported by the contrast in (63): when the minimizer *one person* serves as a subject, its surface position and reconstructed position are both higher than negation; therefore, the ungrammaticality in (63a) cannot be salvaged by reconstruction.

(63) a. *[YI-ge ren]$_F$ **dou** bu renshi Yuehan.
one-CL person DOU NEG know John.
Intended 'no one knows John.'
b. Yuehan [Yi-ge ren]$_F$ **dou** bu renshi.
John one-CL person DOU NEG know
'John doesn't know anyone.'

In (61b), however, under the assumption that John shouldn't want the money if the amount of money is too little, we expect that *John wants one cent* is more unlikely to be true than *John wants two cents*; therefore, the additive presupposition of *dou* can be satisfied even in absence of the post-*dou* negation.

7 Conclusions

In this paper, I offered a uniform semantics to capture the seemingly diverse functions of the Mandarin particle *dou*, including the quantifier use, the FCI-licenser use, and the scalar use. I proposed that *dou* is a special exhaustifier that operates on sub-alternatives and has a pre-exhaustification effect: *dou* presupposes the existence of at least one sub-alternative, asserts the truth of the prejacent and the negation of each pre-exhaustified sub-alternative.

Basically, sub-alternatives are alternatives that are not innocently excludable and are distinct from the prejacent. The pre-exhaustification effect is realized by a basic exhaustifier (viz., the *O*-operator). Depending on the meaning of its associated item, *dou* functions either as a universal quantifier/distributor or as a universal FCI-licenser.

When *dou* is associated with a scalar item, sub-alternatives are the ones that rank lower than the prejacent sentence with respect to the contextually relevant measurement, and the pre-exhaustification effect is realized by the scalar exhaustifier JUST. In particular, in a [*lian* Foc *dou* . . .] sentence, sub-alternatives are the alternatives that are more likely (viz., less unlikely) to be true than the prejacent.

The additive presupposition of *dou* explains the distributional pattern of *dou* and many of its semantic consequences, such as the requirements regarding to distributivity, plurality, and monotonicity, the *even*-like interpretation of the [*lian* Foc/Min *dou* . . .] construction, the distributional pattern of the post-*dou* negation in licensing minimizers, and so on.

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