Proceedings of the 19th International Workshop of Logic and Engineering of Natural Language Semantics 19 (LENLS19)

hosted by The Association for Logic, Language and Information (FoLLI)

Workshop Chair

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Hybrid (Ochanomizu University | Online)
on 19 (Sat), 20 (Sun) November, 2022.

Hybrid (The University of Tokyo, Komaba 1 Campus | Online)
on 21 (Mon) November, 2022.

Preface

This proceedings volume contains selected and invited papers on topics in formal semantics, formal pragmatics, and related fields, including the following:

- ✠ Formal syntax, semantics and pragmatics of natural language
- ✠ Model-theoretic and/or proof-theoretic semantics of natural language
- ✠ Computational approaches to semantics and pragmatics
- ✠ Nonclassical logic and its relation to natural language (especially substructural, fuzzy, categorical, and topological logic)
- ✠ Formal philosophy of language
- ✠ Scientific methodology and/or experimental design in linguistics

LENLS is being organized by an alliance of ”AI systems that can explain by language based on knowledge and reasoning” project (Grant Number JPMJCR20D2), funded by JST CREST Programs ”Core technologies for trusted quality AI systems.”

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The semantic markedness of the Japanese negative preterite:
Non-existence of (positive) eventualities vs. existence of negative eventualities

David Y. Oshima (Nagoya University)

[*Introduction*] In Japanese, the use of a negative preterite (past-perfective) clause is discourse-pragmatically constrained, and oftentimes a negative nonpast-perfect (present-perfect) clause with *-te* IRU (where IRU is a "nonperfective" auxiliary that may receive a wide array of interpretations, including progressive, resultative, and perfect; e.g. Kudo 2020) is used where a preterite clause is expected (Matsuda 2002, Yamashita 2014, Kusumoto 2016). To illustrate, the preterite in (1B$_a$) sounds unnatural, conveying something to the effect that the speaker *could have* hired a new nurse. A nonpast-perfect clause is not pragmatically loaded in the same way, as seen in (1B$_b$) (Npfv = nonperfective, Npst = nonpast, Ger = gerund).

(1) (A and B are medical practitioners.)

A: Anta no tokoro, sengetsu atarashii kangoshi yatotta?
you Gen place last.month new.Npst nurse hire.Pst
'Did you hire a new nurse at your clinic last month?'

B$_a$: #E? **Yatowanakatta** yo. Nande? [preterite]
Intj hire.Neg.Pst DPrt why
(Huh? I didn't hire anyone. Why?)

B$_b$: E? **Yatotte nai** yo. Nande? [nonpast perfect]
Intj hire.Ger NpfvAux.Neg.Npst DPrt why
'Huh? I didn't hire anyone. Why?'

It can be said that, as long as negative clauses are concerned, the nonpast perfect rather than the preterite is the default way to describe a situation in the past.

This work argues that the Japanese negative preterite invariably expresses the occurrence of a "negative eventuality", whose existence and ontological nature have been extensively debated, rather than the non-occurrence of eventualities. It will be furthermore argued that, while in general Japanese nonpast-tensed clauses specify that the topic time (in Klein's 1994 sense) is the present or a future time, this does not necessarily apply to nonpast-perfect clauses, making it possible for a negative nonpast-perfect clause to represent the non-occurrence of events in a past topic time.

[*Background: Negative eventualities*] It has been widely acknowledged in the literature that a negative clause may describe the occurrence (existence) of a negative eventuality, rather than the non-occurrence (non-existence) of eventualities (Krifka 1989; de Swart 1996; Przepiórkowski 1999; Bernard & Champollion 2018; Fábregas & González Rodríguez 2020, among others). Among the most compelling pieces of evidence for "negative eventualities" are: (i) a negative clause can be a complement of a perception verb like SEE, as in (2), (ii) a negative clause may occur in slots like "What happened is ..." and "... is what they did", as in (3), and (iii) the content of a negative clause can be modified with a non-restrictive relative clause, which may modify an eventuality but not a proposition, as seen in (4).

(2) The police officer saw Chris not stop for the traffic light.

(3) What happened next was that the consulate didn't give us our visa. (de Swart 1996:229)

(4) a. John kissed Mary, which {made her angry/*is shown by her blushed face}.
b. John didn't ask Mary to dance at the party, which made her angry.
(adapted from Przepiórkowski 1999:239)

Various proposals have been put forth on the semantics of a negative clause representing the occurrence of a negative eventuality. This work adopts Bernard & Champollion's (2018) idea that each set of eventualities P expressible with a clause nucleus has a negative counterpart, **Neg**(P), which contains all and only those eventualities which preclude—i.e., cannot co-exist in the same world with—every eventuality in P. The incompatiblity of an eventuality and its negative counterpart may be accounted for with an axiom along the lines (5), which mirrors the Law of Contradiction in classical logic.

(5) **Axiom of Negation**: $[\exists e[e \in \mathbf{Neg}(P)]] \leftrightarrow [\neg\exists e'[e' \in P]]$

When P is eventualities whereby Mary leaves, for example, **Neg**(P) is something like eventualities whereby Mary stays.

Bernard & Champollion (2018) assign a meaning along the following lines to English *not*; Subscript E stands for "eventive".

(6) $\text{not}_E \mapsto \lambda P_{\langle v,t\rangle}[\mathbf{Neg}(P)]$

The admittance of negative eventualities in the ontology makes it possible to develop reasonable semantic representations for sentences like (2)–(4). It is an event of "anti-stopping" that is described to have been seen by a police officer, it is an event of "anti-visa-issuance" that is described to "have happened", and so forth.

Now, if a negative clause may describe a negative eventuality, does it always do so? Does, say, English *not* always represent something like (6), or can it represent the classical Boolean negation, i.e. (7) where P stands for "propositional", as well?

(7) $\text{not}_P \mapsto \lambda p[\neg p]$

There is no consensus on this matter in the existing literature. With Przepiórkowski (1999), Higginbotham (2000), and Fábregas & González Rodríguez (2020), I maintain that clausal negation comes in two varieties: propositional negation (7) and eventive negation (6). In a sentence like (8), negation occurs in the complement of a perception verb and is forced to receive the eventive reading. In a sentence like (9), on the other hand, English *not* may, in theory, be either propositional or eventive.

(8) Ken saw Mary not_E dance.
'There was a negative eventuality where Mary danced, and Ken saw it.'

(9) Mary did $\text{not}_{P/E}$ dance.
a. 'There was no eventuality where Mary danced.'
b. 'There was a negative eventuality where Mary danced.'

A negative clause involving propositional negation can be said to express the non-occurrence of eventualities (NOE), and one involving eventive negation the occurrence of a negative eventuality (ONE). (a) and (b) are respectively paraphrases of the ONE and NOE readings of the sentence *Mary did not dance*.

I furthermore suggest that reference to a negative eventuality (corresponding to a dynamic event)—i.e., the ONE reading of a (dynamic) negative clause—is highly constrained, and is available only when the occurrence of a corresponding positive eventuality is or was expected or at least plausible.

It is commonly acknowledged that generally negative sentences are pragmatically more marked than their affirmative counterparts (Tian & Breheny 2019 and references therein). However, there seems to be a significant difference in the degree of markedness between sentences with regular (propositional) negation and ones with eventive negation.

In a context where there has been no expectation for Mary to take a picture, let alone a picture of an eggplant, the negative sentence in (10a) would be a fairly strange thing to say. It nevertheless is judged as a true statement, if indeed Mary did not take a picture of an eggplant. The second sentence in (10b), on the other hand, does not merely sound odder than that in (10), but seems not to be true. It is not clear if it is even a false statement—it has a flavor of presupposition failure.

(10) a. I observed Mary for three hours. She did not take a picture of an eggplant.
b. I observed Mary for three hours. #I saw her not take a picture of an eggplant.

It seems thus sensible to suppose that the occurrence of eventive negation is much more constrained than that of propositional negation.

The logical translations of "Moe didn't sing" on the NOE and ONE readings will look like (11a,b):

(11) Moe didn't sing.

a. $\neg\exists e$[**TT** $<$ **TU** & **At**(e,**TT**) & **sing**(e) & **Actor**(e) = **moe**]]]] (NOE)

b. $\exists e$[**TT** $<$ **TU** & **At**(e,**TT**) & **Neg**(λe'[**dance**(e') & **Actor**(e') = **ken**])(e)] (ONE)

TT and **TU** represent the topic time (Klein 1994) and the time of utterance, respectively. The logical predicate **At** (cf. Condoravdi 2002:70) is defined in (12). τ represents a temporal trace function (Krifka 1989:97), and "$\subseteq$" stands for temporal inclusion.

(12) $$\mathbf{At}(e,t) =_{def} \begin{cases} \tau(e) \supseteq t & \text{if } e \text{ is stative} \\ \tau(e) \subseteq t & \text{otherwise} \end{cases}$$

[*The markedness of the Japanese negative preterite*] It has been observed in the descriptively oriented literature on Japanese that the use of a negative preterite is rather strictly constrained, unlike its nonpast counterpart (Matsuda 2002, Yamashita 2014, Kusumoto 2016). At the descriptive level, one may say that a negative preterite conveys that the logical contrary of its propositional content—e.g. the speaker's hiring a new nurse in the case of (1)—was considered plausible by the speaker at some point prior to the discourse. A puzzle, however, is what brings about such an effect.

I propose that the negation in a Japanese negative preterite is invariably eventive, so that, for example, 13 allows only the ONE reading.

(13) Ken wa utawanakatta.
K. Top sing.Neg.Pst
'Ken did not sing.'

a. #$\neg\exists e$[**TT** $<$ **TU** & **At**(e,**TT**) & **sing**(e) & **Actor**(e) = **ken**]]]] (NOE)

b. $\exists e$[**TT** $<$ **TU** & **At**(e,**TT**) & **Neg**(λe'[**dance**(e') & **Actor**(e') = **ken**])(e)] (ONE)

The plausibility requirement for a Japanese negative preterite straightforwardly follows from this supposition.

[*The quasi-preterite interpretation of the nonpast perfect*] The puzzle of the limited discourse-configurational distribution of the negative preterite has a flip side: the unexpectedly wide distribution of the negative nonpast perfect. Assuming the Parsonsian (resultativity-based) account of the perfect (Parsons 1990), and adopting the premise that a nonpast tense specifies that the topic time is set to some nonpast (present or future) time, the logical representations of the boldfaced parts of (14B$_{a,b}$) should look like (15a,b). The function **RS** maps an eventuality to its resultant state. ((14B$_b$) in theory may receive the NOE reading, but here it is taken to receive the ONE reading.)

(14) (A big soccer game was broadcast on TV the evening before.)

A: Kinoo, sakkaa mita?
yesterday soccer see.Pst
'Did you watch the soccer game yesterday?'

B$_a$: Un, **mita**. Sono tame ni zangyoo mo kotowatta n da.
yes see.Pst that purpose Dat overtime.work also resufe.Pst DAux Cop.Prs
'Yes, I watched it. I refused to work overtime for that purpose.'

B$_b$: Iya, **mite nai**. Mitakatta kedo, zangyoo ga atte.
no see.Ger NpfvAux.Neg.Npst see.want.Pst though overtime.work Nom exist.Ger

'No, I did not watch it. I wanted to watch it, but I had to work overtime.'

(15) a. $\exists e[\mathbf{TT} < \mathbf{TU}$ & $\mathbf{At}(e,\mathbf{TT})$ & $\mathbf{watch}(e)$ & $\mathbf{Actor}(e) = \mathbf{Speaker}$ & $\mathbf{Undergoer}(e) = \textbf{the-game}]$
b. $\neg\exists e[\exists e'[\mathbf{TU} \leq \mathbf{TT}$ & $\mathbf{At}(e,\mathbf{TT})$ & $e = \mathbf{RS}(e')$ & $\mathbf{watch}(e')$ & $\mathbf{Actor}(e') = \mathbf{Speaker}$ & $\mathbf{Undergoer}(e') = \textbf{the-game}]]$

It is counterintuitive, however, to suppose that the relevant parts of (14B$_{a,b}$) are "about" different temporal scenes; (14B$_b$) strikes as being "about" the evening before—a past time—to the same extent as (14B$_a$) does.

I suggest that the Japanese perfect, expressed with IRU, optionally poses a restriction on the topic time, specifying that it includes the time of the source event and is prior to the time of utterance; the underline in (16) indicates optionality.

(16) PERFECT$_{\text{Jpn}}$ = $\lambda P[\lambda e[\exists e'[\underline{\mathbf{TT} < \mathbf{TU} \text{ \& } \mathbf{At}(e',\mathbf{TT}) \text{ \& }}\ e = \mathbf{RS}(e')$ & $P(e')]]]$

I furthermore suggest that the Japanese nonpast tense is semantically vacuous, and the use of a nonpast tense conveys that the described eventuality occurs in a nonpast time only as an implicature arising from the absence of a past tense (cf. Sauerland 2002).

(17) a. PAST$_{\text{Jpn}}$ = $\lambda P[\lambda e[\mathbf{TT} < \mathbf{TU}$ & $\mathbf{At}(e,\mathbf{TT})$ & $P(e)]]$
b. NONPAST$_{\text{Jpn}}$ = $\lambda P[P]$

One piece of evidence for the semantic vacuity of the Japanese nonpast tense is that, when nonpast and past features co-occur within the same complex predicate the whole predicate is interpreted as referring to a past time (Plt = polite(ness)).

(18) a. Mimas**en** deshi**ta**.
see.Plt.Neg.Npst PltAux.Past
'(*pro*$_i$) did not see (*pro*$_j$). (Polite)'

b. Aokat**ta** des**u**
blue.Pst.Pst PltAux.Npst
'(*pro*$_i$) was hot. (Polite)'

The optional component of the semantics of the perfect leads to the two distinct representations of (19), one of which can be characterized as a "quasi-preterite" interpretation. The shaded part in (19a) is a pragmatically enriched content.

(19) Ken wa **utatte** **inai**.
K. Top sing.Ger Npfv.Npst
a. 'Ken {has not/will not have} sung.' [regular nonpast-perfect]
$\neg\exists e[\exists e'[\mathbf{TU} \leq \mathbf{TT}$ & $\mathbf{At}(e,\mathbf{TT})$ & $e = \mathbf{RS}(e')$ & $\mathbf{sing}(e')$ & $\mathbf{Actor}(e') = \mathbf{ken}]]$
b. 'Ken did not sing.' [quasi-preterite]
$\neg\exists e[\exists e'[\mathbf{TT} < \mathbf{TU}$ & $\mathbf{At}(e',\mathbf{TT})$ & $e = \mathbf{RS}(e')$ & $\mathbf{sing}(e')$ & $\mathbf{Actor}(e') = \mathbf{ken}]]$

The proposed analysis has the additional merit of accounting for how an *affirmative* nonpast perfect clause may receive a preterite-like interpretation (with a certain rhetorical effect), as seen in (20) (adapted from a Wikipedia article).

(20) Korera ichiren no undoo no tame ni, Gandhi wa tabitabi toogoku sareta.
these serial Cop.Attr movement Gen cause Dat G. Top frequently imprison do.Psv.Pst
Tatoeba 1922-nen 3-gatsu ni wa, 2-nen-kan no fufukujuu undoo no
for.example 1922-year 3-month Dat Top 2-year-for Cop.Attr disobedience movement Gen
tame ni, 6-nen-kan no chooekikei no hanketsu o **ukete** **iru**.
cause Dat 6-year-for Cop.Attr imprisonment Gen judgment Acc receive.Ger NpfvAux.Prs

‘Gandhi was frequently imprisoned for this series of movements. For example, on March 1922, he was sentenced to six-year imprisonment for a two-year long civil disobedience movement.’

[*Why is* -ta *incompatible with the NOE negation?*] A likely cause of the incompatibility of the past marker *-ta* with propositional negation is s its grammatical status/position. As discussed by Oshima (2014), *-ta* can sensibly be regarded as a particle separated from its host by a word boundary, unlike nonpast suffixes like -(*r*)*u*. It is, on the other hand, a general fact in Japanese predicate morphology/syntax that in a configuration where a predicate P is followed by an element E (e.g., an auxiliary), a component within P cannot semantically outscope (a component within) E.

(21) a. Shikaranaide ageru.
scold.NegGer BenAux.Npst
‘(*pro*$_i$) will benefit (*pro*$_j$) by not scolding (*pro*$_{j/k}$)’ (Ben > Neg)

b. Shikatte agenai.
scold.Ger BenAux.Neg.Npst
‘(*pro*$_i$) will not benefit (*pro*$_j$) by scolding (*pro*$_{j/k}$)’ (Neg > Ben)

It seems thus quite plausible that the word boundary blocks negation in the host to take scope over *-ta*, thereby inducing the differing scopal behaviors of the nonpast and past tense markers (Neg > Nonpast, Nonpast > Neg, Past > Neg, *Neg > Past). Under the current analysis of tenses and propositoinal/eventive negations, due to their semantic types, propositional negation ($\langle t, t\rangle$) must be applied after the closure of the eventuality variably, hence taking scope over the tense; eventive negation ($\langle vt, vt\rangle$), on the hand, may take scope under the tense ($\langle vt, vt\rangle$). The impossibility of the “Neg > Past (*-ta*)” pattern implies that the negation occurring in a preterite can only be eventive.

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Semantic Properties of the Japanese Emphatic Minimizer "NP-*no-kakera*"

Based on the Modal Base

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1. Outline

Sawada (2022) suggested that a Japanese emphatic minimizer NP-*no-kakera-mo* ("a shred of NP") is an NPI with an at-issue meaning in (1a) and the meaning of "expectation" and "complain" as non-at-issue meaning as in (1bc).

(1) Ano-seijika-ni-wa seijitsusa-no-kakera-mo nai.
that- politician-DAT-TOP sincerity-GEN-piece-even NEG
"That politician does not have a shred of sincerity."
a. That politician does not have sincerity. (at-issue meaning)
b. Politicians should have sincerity. (expectation)
c. I am frustrated that that politician does not have sincerity. (complaint)

Sawada (2022) analyzes these non-at-issue meanings as conventional implicature (CI) with multidimensional meanings (Potts 2005, 2007; McCready 2010; Sawada 2018). I demonstrate that Sawada's descriptive generalization has systematic counterexamples and provide a more accurate generalization behind the various meanings of NP-*no-kakera-mo nai* ("not a shred of NP"). I propose an analysis that these non-at-issue meanings are derived from the essential meaning of the NP-*no-kakera-mo* and negation, so there is no need to set up the specific meaning such as "expectation" and "complain" as CI. I demonstrate that the NP-*no-kakera* is an inherently modal expression and that it refers to something that minimally exists in the modal base that is covertly introduced at the non-at-issue level. In other words, *kakera* is a "thorough" minimizer (as it were), so much so that it invokes minimization even in modal bases; hence, it produces expressive effects that neutral minimization does not. I further argue that the non-at-issue meaning based on a modal base, set by the contexts and knowledge of the attitude holder (typically the speaker), is neither a "typical" presupposition nor conventional implicature, which Potts (2005) proposed originally.

2. Problem

Kakera literally means "piece" and is used as an emphatic negative polarity item (NPI) with the focus particle *mo* ("even") as in (1). Sawada (2022) argues that non-at-issue meanings as in (1bc) are CI because they are not negated by B's replies in contexts such as in (2).

(2)A: Ano-seijika-ni-wa seijitsusa-no-kakera-mo nai.

"That politician does not have a shred of sincerity."

B: Iya, sore-wa uso-da.

No that-TOP false-PRED

"No, that's false." (Sawada 2022: 5)

Sawada's (2022) analysis captures only one aspect of the whole set of empirical properties of NP-*no-kakera*. NP-*no-kakera-mo nai* ("not a shred of NP") may express neither "expectation" nor "complain" as in (3). The speaker in (3) seems to be favorably impressed by "Taro's lack of rusticity."

(3) Hisabisani at-ta taro-wa inakakusasa-no-kakera-mo kanji-rare-nakat-ta.

In-ages meet-PST Taro-TOP provincialism-GEN-piece-even feel-PASS-NEG-PST

"Taro, whom I hadn't seen in a while, didn't have an air of provincialism."

Sawada (2022) claims that the NP in NP-*no-kakera* should be positive abstract nouns and that examples such as (3) are peripheral examples in which *kakera* occurs with a negative abstract noun. However, *kakera* with negative (or neutral) noun meanings are systematically productive expressions, as we will see later. Thus, it is undesirable to regard them as peripheral examples.

3. Proposal

I argue that the meaning of NP-*no-kakera* indicates something that minimally exists in a modal base in Kratzer's (1981) sense. For example, (4), as it is, seems unnatural compared to (5), which contains a neutral NPI *sukoshimo* ("at all"). However, if we set up a context that the speaker thinks that Yamada-kun must be an irresponsible person, as in (6), it becomes perfectly natural. This is because the context introduces the modal base that Yamada should be irresponsible at least minimally in any possible world. This phenomenon indicates the validity of the direction of the analysis in this presentation.

(4)??Yamada-ni-wa musakininsa-no-kakera-mo nai.

Yamada-DAT-TOP irresponsibility-GEN-piece-even NEG

"Mr. Yamada does not have an ounce of irresponsibility."

(5) Yamada-ni-wa musakininsa-ga sukoshi-mo nai.

Yamada-DAT-TOP irresponsibility-NOM a-little-bit-even NEG

"He has no irresponsibility at all."

(6) Kenkyuushitsu-de-no yamada-no yoosu-ni-wa,

Laboratory-LOC-GEN Yamada-GEN appearance-DAT-TOP

hudan-no-kare-no musekininsa-no-kakera-mo kanji-rare-nai.
usual-GEN-he-GEN irresponsibility-GEN-piece-even feel-PASS-NEG
"Yamada's behavior in the lab shows no sign of his usual irresponsibility."

NP-*no-kakera-mo nai* can express various modal meanings depending on the modal base types that are set within the knowledge or situation assumed in the discourse.

(7) Deontic (e.g., Minimum properties a teacher must possess)
Tanaka-senei-ni-wa seijitsusa-no-kakera-mo nai. Komat-ta mono-da.
Tanaka-Mr.-DAT-TOP sincerity-GEN-piece-even NEG. Complain-PST-NMLZ-PRED
"Dr. Tanaka does not have a shred of sincerity. It's a problem."

(8) Bouletic or teleological (e.g., Minimum required to accomplish the project)
Kiryoku-no-kakera-mo nokot-tei-nakat-ta-node, purojyekuto-wo
Energy-GEN-piece-even leave-ASP-NEG-PST-because project-ACC
tatamu-koto-ni shi-ta. Demo, kookai-wa shi-tei-nai.
close-NMLZ-DAT do-PST. But regret-TOP do-ASP-NEG
"I didn't have a shred of energy left, so I decided to fold the project. But I have no regrets."

(9) Epistemic (e.g., The minimum psychological stress that Yoko has, as foreseen by speaker's knowledge)
Yoko-wa daibutai-de kinchoo-no-kakera-mo mise-zuni engishi-ta.
Yoko-TOP big-stage-LOC nervousness-GEN-piece-even show-NEG performe-PST
Watashi-ga shit-tei-ru kanojyo-to-wa betsujin-no yoo dat-ta.
I-NOM know-ASP-PRS she-with-TOP different-person-GEN look PRED-PST
"Yoko performed without a shred of nervousness on the big stage. She was like a different person from the one I knew."

(10) Stereotypical (e.g., Minimum properties that a typical politician possesses)
(Politicians are more or less arrogant, but) Tanaka-sensei-ni-wa koomansa-no-
Tanaka-Mr.-DAT-TOP arrogant-GEN-
kakera-mo nai. Dakara kare-wo sonkei-shi-tei-ru.
piece-even NEG. So he-ACC respect-do-ASP-PRS
"Politicians are more or less arrogant, but Mr. Tanaka has no trace of arrogance. That is why I respect him."

According to (7)-(10), the meaning of "expectation" and "complain" are not lexical meanings of NP-*no-kakera* but they are implicature derived from the whole sentence only when NP-*no-kakera-mo* is based on the deontic modal base. Specifically, when NP-*no-kakera* denotes that something must exist at least minimally in the deontic modal base (e.g., the sincerity of the teacher in (7)), the whole sentence means that something that should be there at least minimally is not there. The meaning of "expectation" and "complain" are only the presumption that hearers make from the whole sentence, so they cannot be negated by the reply as in (2B). Similarly, the positive bias noted by Sawada that NPs used in the NP-*no-kakera* tend to possess arises only as a matter of common knowledge, in which many of the properties registered as something that minimally {must exist/ should exist/exist to achieve the goal} in various modal bases are positive properties.

The crucual examples are those in (8)-(10). These examples are associated with modal bases that are not deontic. As showin in (8)-(10), in all these cases, a follow-up with a sentence that contradicts speaker's complaint is perfectly natural, clearly conterexemplifying Sawada's claim in (1). When the NP-*no-kakera* denotes something that minimally exists in the bouletic or teleological modal base (e.g., the motivation to complete the project in (8)), the whole sentence means that something that must be there to achieve the goal is not there regardless of whether the speaker is dissatisfied. The same applies to (9) and (10). NP-*no-kakera* denotes something that minimally exists in the epistemic or stereotypical modal base, like the nervousness that Yoko must have on the stage, at least a little, in (9) or the arrogance that any typical politician has, at least a little, in (10).

4. The semantic properties of the non-at-issue meaning of NPI *kakera*

Based on the discussion so far, I propose the meaning of NPI *kakera* as follows.

(11) Ano-seijika-ni-wa seijitsusa-no-kakera-mo nai. (=(1))

a. That politician does not have sincerity. (at-issue meaning)

b. Politicians must be at least a little sincere (non-at-issue meaning)

I will show that this non-at-issue meaning based on the modal base is neither a presupposition nor CI (which at least Potts (2005) first proposed) from the viewpoints that it can be a local (subject-oriented) interpretation when it is embedded in the attitude verbs as in (12) (unlike CI such as a non-at-issue meaning in appositive) and and that it needs no common ground between speaker and listener as in (13) (unlike a presupposition such as a non-at-issue meaning in additive particles such as "too" and "also").

(12) [The speaker$_i$ believes he speaks frankly.] Yoko-wa, kyoo-no watasi$_i$ -no

Yoko-TOP today-GEN I-GEN

hatsugen-wa mezurashiku gomakashi-no-kakera-mo nai-to omot-ta-souda.

speech-TOP unusually deception-GEN-kakera-even NEG-COMP think-PST-seem

"Yoko did not seem to think there was not a shred of deception in what I said today, which was unusual."

(13) A: Kenkyuushitsu-de-no yamada-no yoosu-ni-wa, hudan-no-kare-no musekininsa-no-kakera-mo kanji-rare-nai.(=(6))

"Yamada's behavior in the lab shows no sign of his usual irresponsibility."

B: Soo? Somosomo, Yamada-wa hudan-kara musekinin-de-wa

Is-that-so? To-begin-with, Yamada-TOP usual-from irresponsible-COP-TOP

nai-to omou-yo.

NEG-COMP think-FP

"Is that so? To begin with, I don't think Yamada is usually irresponsible."

5. Conclusion and open question

This presentation approached the non-at-issue meanings of "expectation" and "complain" of NP-*no-kakera* analytically from the modal base. This argument suggests that some expression that needs to refer to the modal base yields the non-at-issue meaning based on the attitude holder's belief consequently. Finally, although I remain to clarify the semantic status of the modal base that is covertly introduced at the non-at-issue level as an open question in this presentation, I pointed out that this type of non-at-issue meaning is not analyzed as a presupposition or CI at least in typical.

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Slurs' variability, emotional dimensions and game-theoretic pragmatics

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1 Introduction

Slurs' meaning is unstable. A slurring utterance like 'Hey, F, where have you been?' (where F is a slur) may receive a wide array of interpretations depending on various contextual factors: the speaker's identity, her relation to the addressee, her intonation, etc (Davis and McCready, 2020). Standard semantic, pragmatic, and non-content theories of slurs have issues to account for some or all kinds of variability observed. To solve this, I argue that slurs don't convey emotional categories such as 'contempt' but emotional dimensional qualities such as, e.g., 'negative valence, neutral arousal, high dominance'. Then, I show how to translate this thesis into a detailed game-theoretic model of slurs use and interpretation inspired by the work of Heather Burnett (2019). This new approach, called 'Affective Meaning Games' (AFM), captures slur's variation and situates pragmatic reasoning within an independently motivated psychological account of emotional states.

2 Two types of variation

Slurs' variation is janus-faced. On the one hand, speakers *express* a wide array of emotions by using slurs. Typically, speakers can display negative emotions such as contempt (i.e. 'Fs are not allowed here') or fear (i.e. 'Fs are invading us') by uttering a slur. Yet, in other situations, when the slur is used among members of the target group, the speaker is typically characterized as expressing positive emotions, such as solidarity (i.e., 'Hey, my F, I missed you') or pride (i.e., 'We should be proud of being Fs').

On the other hand, speakers *elicit* different degrees of offense by using slurs. Indeed, slur's offensiveness may vary i) across different lexical items, even when they are co-referential (e.g., 'beaner' may be considered more offensive than 'greaser'), and ii) across different uses of the same expression, depending on who uses it (e.g., uses of 'fag' within the LGTB community are considered less offensive those performed by outsiders) or how it is used (e.g., with a contemptuous or friendly intonation).

Importantly, it has been observed that the offense a slur elicits is independent of the valence of the emotion it expresses (Popa-Wyatt and Wyatt, 2017). Uses of 'spade' among hippies were often described as genuinely expressing appreciation or endearment towards Afro-Americans, but were nonetheless considered offensive (Nunberg, 2018). Conversely, uses of slurs that target dominant groups (e.g., 'limey') can express extreme contempt or disgust, but are nonetheless regarded as inoffensive.

Should we conclude that slurs' offensiveness is independent of the emotions they express? In what follows I argue that this is not the case. To wit, emotions are not only understood as discrete emotional categories (e.g., 'contempt'), but also as states that can be characterized using broad affective dimensions (i.e., valence, arousal, and dominance). In a nutshell, I argue that the degree of dominance expressed by a slur is at the root of its complex offensive profile.

3 Slurs and PAD theories of emotions

According to the classical view, each basic emotional category, such as happiness or disgust, triggers a distinct set of behavioral and physiological responses. However, in the absence of evidence for a clear one-to-one correspondence between emotions and bodily patterns (Barrett, 2017), researchers have proposed to characterize affective episodes using the following continuous, bipolar, and orthogonal dimensions (Mehrabian and Russell, 1974):

- PLEASURE: evaluative dimension ranging from negatively valenced affective states (e.g., sadness) to positively valenced ones (e.g., happiness).
- AROUSAL: physiological dimension ranging from low mental alertness (e.g., boredom) to high mental alertness (e.g., excitement).
- DOMINANCE: relational dimension ranging from the sensation of feeling submissive (e.g., frustration) to the sensation of feeling in control or powerful (e.g., anger).

This psychometric approach to affective phenomena, also known as the 'PAD' theory of emotions, is widely applied in the analysis of affective episodes in a continuous rather than discrete framework. Even though DOMINANCE is sometimes omitted (Russell and Pratt, 1980), it is at the basis of recent accounts of social perception based on facial features (Oosterhof and Todorov, 2008) and, moreover, it allows us to distinguish affective states such as anger and frustration, alertness and surprise, etc. (Mehrabian, 1996).

For example, anger and frustration are typically highly arousing, negative emotions, but differ in the extent to which the agent feels free to respond to the stimulus. In the presence of individuals judged to be less dominant (e.g., a subservient), an offense is more likely to elicit anger than frustration. In this sense, the dominance experienced by an agent is inversely proportional to the assessed dominance (i.e., physical strength, social status, aggressiveness) of the stimulus (Mehrabian and Russell, 1974).

How are the states expressed by slurs related to the PAD dimensions?

1. Slurs typically express the speaker's negative evaluation of the target group. By saying 'That building is full of Fs' the speaker is more likely interpreted

as expressing DISPLEASURE with respect to F's target.

2. Slurs don't seem to be statistically related to a particular degree of AROUSAL. Unlike other swear words (e.g., 'fucking'), slurs don't come as infelicitous in contexts where the speaker doesn't feel intense emotions.
3. Finally, slurs typically express that the speaker feels superior with respect to the target group. That is, slurs express that targets rank as low in worth with respect to the speaker, who thereby presents himself as DOMINANT.

The reasons why slurs convey a high degree of dominance are plausibly related to the social context in which they circulate: slurs are typically coined and used by dominant groups, they often precede or co-occur with other types of aggression, etc. Yet, it has been assumed that expressing that individuals are inferior is itself a form of negative evaluation (Jeshion, 2016). However, both dimensions can be distinguished: one can evaluate someone negatively without feeling that he is lesser, and one can feel that someone is lesser without evaluating him negatively. Thus, realizing that some emotions can be positive but nonetheless involve a threat of aggression (e.g., amusement at someone's expense) allows us explain slurs' offensiveness. Now, I will translate this hypothesis (which we may call 'the valence-dominance' view) into a formal theory of slur's use and interpretation.

4 Affective Meaning Games

How can we define emotional states in a theory of meaning? Inspired by Burnett (2019), I assume a structure $\langle \mathbb{Q}, > \rangle$, where $\mathbb{Q}$ is a set of relevant affective qualities (e.g., positive pleasure or '[P+]') and > encodes relations of incompatibility between them (e.g., individuals cannot be in a [P-] and [P+] state simultaneously). Since slurs don't correlate with a specific degree of arousal, this dimension is not included:

(1) $\mathbb{Q}$ = {[P+], [P-], [D-], [D+]}
  a. [P+] > [P-]
  b. [D-] > [D+]

Based on $\langle \mathbb{Q}, > \rangle$, we derive 4 types of affective states α: e.g., the [P-, D+] state, labeled CONTEMPT, etc. Importantly, these labels serve to assemble different discrete emotional categories. For example, CONTEMPT represents [P-, D+] states in general (e.g., rage, hostility, etc.), and not only contempt:

(2) Affective states (AFF):

AFF	AFFILIATION	AMUSEMENT	ANXIETY	CONTEMPT
α	[P+, D-]	[P+, D+]	[P-, D-]	[P-, D+]

Then, we assume that for some slurring term F there is a co-referential non-slurring alternative F*. How can we characterize the relation between F/F* and affective states *alpha*? We have assumed that slurs are more strongly associated with [D+]

states (e.g., AMUSEMENT), etc. To capture such statistical regularities, I associate F with the probability distribution $\Pr(F|\alpha)$, read as 'the likelihood of uttering a slur F given an affective state α'. Note that the alternative F* is associated with the distribution $\Pr(F*|\alpha)$ = 1 - $\Pr(F|\alpha)$:

(3) Affective meaning of F and F*:

AFF	AFFILIATION	AMUSEMENT	ANXIETY	CONTEMPT
$\Pr(F\|\alpha)$	0.3	0.6	0.4	0.7
$\Pr(F*\|\alpha)$	0.7	0.4	0.6	0.3

Finally, once S utters a slur F directed at a social group G, the L's prior beliefs are updated using Bayes rules. That is, by conditioning his prior beliefs '$\Pr(\alpha)$' (i.e., the prior probability that S feels a with respect to G') on F's affective meaning. Prior probabilities vary with respect to multiple factors: the speaker's identity, her social relation to the addressee, etc. If S is catholic, we assume that he feels positive about the Catholic church; if S and L are friends, that S doesn't consider L as lesser, etc. Even though such assumptions may be proven incorrect, social identities guide how others think about others' emotions (Appiah, 2010).

Thus, reasoning about the S's potential emotions towards G can change the weighting of the affective states α in a given context, thus giving rise to the variation observed in Section 2. For example, in a situation where L hears S using 'spic', and where S is not Latino, the slur will be interpreted as offensive. How can we explain this? In this case, we assume that L doesn't have any prior expectations about S's affective dispositions toward Latinos. Thus when S uses the slur, L's prior beliefs are updated by the affective meaning of 'spic'. As a result, we obtain that L will interpret S as more likely expressing CONTEMPT (cf. the fourth row):

(4) L's beliefs after hearing S saying 'spic':

AFF	AFFILIATION	AMUSEMENT	ANXIETY	CONTEMPT
$\Pr(\alpha)$	0.25	0.25	0.25	0.25
$\Pr(spic\|\alpha)$	0.3	0.6	0.4	0.7
$\Pr(\alpha)\cdot\Pr(spic\|\alpha)$	0.075	0.150	0.100	0.175
$\Pr(\alpha\|spic)$	0.15	0.3	0.2	0.35

In contrast, in a situation where L knows that S is Latino, his utterance of 'spic' will be interpreted as non-offensive. In this situation, L will probably expect S to feel [P+] and [D-] states towards Latinos, as it is implausible to feel members of one's group as worth of contempt (e.g., Pr(AFFILIATION = 0.6). Thus, when L's prior beliefs are updated by the meaning of *spic*, we obtain that L will interpret S as more likely expressing *affiliation* towards that group (e.g., $\Pr(\text{AFFILIATION}|spic) = 0.537 > \Pr(\text{CONTEMPT}|spic) = 0.104$).

By taking into account formal models of emotions, and in particular PAD models, into the calculation of the affective content conveyed by slurs, Affective Meaning

Games help us understand i) how slurs can be interpreted as expressing a wide array of emotions depending on listeners' prior assumptions and ii) how the valence-dominance hypothesis can serve to explain slur's offensiveness.

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Granularity in number and polarity effects

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Introduction The recent literature on the polarity phenomena has revealed that vagueness and granularity have an impact on the polarity effect (e.g., Solt (2018) on approximators such as *approximately, about*, Goncharov and Wolf (2021) on *some* NP and minimizers). This work is yet another contribution to this trend, reporting an unnoticed contrast between round and non-round numbers when associated with focus particles in Japanese. Our proposal is that non-round numbers compete with round numbers in computing the (scalar) presupposition of these particles.

Data It has been documented in the Japanese traditional descriptive grammars that numerals marked by focus particle *mo* 'even' cannot be in the scope of negation when the numeral it attaches to is a non-round number, such as 48 (Ijima (1995)).

Consider first (1a), where a round number, 50, is used. (1a) is three-way ambiguous, as shown in (1b)-(1d). The first two interpretations differ truth-conditionally: in a context where 200 people were expected to come and 150 people came, and 50 people didn't show up, (1c) is true but (1b) is not. They also differ in implication. In (1b), the number '50' is taken to be a small number, while in (1c), it is taken to be large. We call these two readings a small and a large readings (Nakanishi (2006)). (1b) and (1d) are the same truth conditionally, but they differ in the implication: the latter implicates that '50' is a large number. We dub this reading 'a large and fewer than n' reading.
This ambiguity is explained when we assume a scope theory of *even* for Japanese *mo*, following Nakanishi (2006). Nakanishi (2006) assumes that *mo* is a propositional operator even if it is appended to a DP, and the operator induces a scalar presupposition, where the prejacent is required to be the least likely one among its alternatives (=(2a)). "Less likely" is here understood to be asymmetric entailment, as in (2b). The small reading results for (1b), because for the prejacent to be the least likely, the alternative propositions need to refer to larger numbers. Likewise, in (1c) and (1d), the presupposition is satisfied in a context where propositions that include smaller numbers than '50'.

(1) a. 50-nin-mo ko-nakat-ta
 50-CL-even came-NEG-PAST
 (lit.) "Even 50 people didn't come."

 b. mo $>$ $\neg$ $>$ 50:
 Assertion: No more than 50 people came.
 Implication: '50' is a small number. small reading

 c. mo $>$ 50 $>$ $\neg$:
 Assertion: There were 50 people who didn't come.
 Implication: '50' is a large number. large reading

 d. $\neg$ $>$ mo $>$ 50:
 Assertion: No more than 50 people came.
 Implication: '50' is a large number. large-and-fewer-than-n reading

(2) a. $[\![\text{mo}]\!]^{c,w} = \lambda p.\ p(w) = 1$, defined if $\forall q \in C[p \neq q \rightarrow p <_{\text{likely}} q]$

 b. p is less likely than q iff p entails q but not vice versa.

(3) a. (1b): mo [$\neg$ 50 people came] is defined, if
‘$\neg$ 50 people came’ entails ‘$\neg$ 51/52/53 . . . people came’

b. (1c): mo [$\exists$x. people(x) $\wedge$|x| = 50 $\wedge$ $\neg$ x came] is defined, if
‘$\exists$x.people(x) $\wedge$| x |= 50 $\wedge$ $\neg$ x came’ entails ‘$\exists$x. people(x) $\wedge$|x| = 49/48/47 . . . $\wedge$ $\neg$ x came’

c. (1d): $\neg$ [mo [50 people came]] is defined, if
‘50 people came’ entails ‘49/48/47 . . . people came.’

When we replace ‘50’ with ‘48’, as in (4), the small reading where [mo $>$ $\neg$ $>$ 48] is not available, and only the large readings are available. Since in the affirmative, the round vs. non-round contrast is not observed (=(5), this happens when *mo* and numerals are intervened by $\neg$.

(4) 48-nin-mo ko-nakat-ta
48-CL-even came-NEG-PAST
(lit.) “Even 48 people didn’t come.” *mo $>$ $\neg$ $>$ 48, OK $\neg$ $>$ mo $>$ 48, OK mo $>$ 48 $>$ $\neg$

(5) {50/48}-nin-mo kita.
{50/48}-CL-EVEN came.
”Even 50/48 people came.”

English also exhibits the same contrast between round and non-round numbers. English *even* behaves differently from Japanese *mo*, in that *even*-sentences have only a small reading when they are in negative. Thus when a non-round number is used in this context, the *even*-sentence sounds bizarre:

(6) a. John didn’t even solve {50/#48} problems.

b. Not even {50/#48} people came.

Granularity in number We propose that the contrast observed between (1a) and (4) is the result of the interaction between granularity in the interpretation of numerals and the semantics of *mo*. Following Sauerland and Stateva (2007), we assume that granularity is a contextual parameter of interpretation. The granularity function, $\mathbf{gran}_i$, maps a number, n, to an interval [n $-$ 1/2$\times i$ $\leq$ n $\leq$ n + 1/2$\times i$], where i represents the granularity level. In this interpretation, 50_{gran10} refers to the interval between [45-55]. The maxim of Manner requires the shortest expression be used for each interval, which prevents ‘48’ from denoting the [45-55] interval (cf. Krifka (2009)).

(7) a. $[\![50]\!]^g$ = $\mathbf{gran}_{10}$(50) = [45-55]

b. $[\![48]\!]^g$ = $\mathbf{gran}_{1}$(48) = [47.5-48.5]

According to this interpretation, in a situation where ‘48_{gran1} people came’ is true, you can truthfully say that ‘50_{gran10} people came’, but not vice versa. This entailment relation holds when a number interpreted with a finer granularity function falls within the range of a number interpreted with a coarser granularity function.

To state this relation, we first define the relative coarseness among granularity functions for numbers as in (8), based on (Sauerland and Stateva 2007:233):

(8) **gran** is finer than **gran'** iff
for all numbers n: max(**gran**(n)) $-$ min(**gran**(n)) $<$ max(**gran'**(n) $-$ min(**gran**(n))

(9) is now understood to be an asymmetric entailment relation between round and non-round number sentences.

(9) Let **gran** be finer than **gran'** and n and m be variables for numbers.
For any number n, if there is a context c and a number m such that if **gran**(n) $\subset$ **gran'**(m), then $[\![\phi(\mathrm{n})]\!]^{\mathrm{c,gran}} = 1 \rightarrow [\![\phi[\mathrm{n/m}]]\!]^{\mathrm{c,gran}'} = 1$, where ϕ does not contain $\neg$.

Polarity effects explained Our proposal is that when the number contained in a proposition satisfies the property in (9), the number with a coarser granularity also counts as an alternative to the number with a finer granularity. Thus as shown in (11b), the proposition that contains 48_{gran1} invokes "$\neg$[50_{gran10} people came]" as its alternative, in addition to the propositions with the same granularity level. This additional alternative does not affect the scalar presupposition of *mo* when the prejacent is in affirmative. In (10a), the prejacent '50 people came' is evaluated against the alternatives with the same granularity level, and results in a large reading for '50'. '48 people came' in (10b) includes alternatives with **gran**$_1$, as well as **gran**$_{10}$. The scalar presupposition of (10b) is satisfied because '50_{gran10} people came' is entailed by '48_{gran1} people came.'.

(10) a. mo $>$ 50: 50_{gran1} people came entails 49, 48, 47 ... people came.
The same holds for 50_{gran10}.

b. mo $>$ 48:
48_{gran1} people came entails 47, 46, 45 ... people came.
48_{gran1} people came entails 50_{gran10} people came. (cf. (9))

When it comes to negative sentences, the interpretation with [mo $> \neg >$ n] requires [$\neg\ \phi$(n)] to be the least likely proposition. This asymmetric entailment relation cannot hold it n = 48, because 'fewer than 48_{gran1} people came' does not entail 'fewer than 50_{gran10} people came' (=(11b).

(11) a. mo $> \neg >$ 50:
$\neg$ [50_{gran10} people came] entails $\neg$ [60/70/80 ... people came]
$\neg$ [50_{gran1} people came] entails $\neg$ [51/52/53 ... people came]

b. mo $> \neg >$ 48:
$\neg$ [48_{gran1} people came] entails $\neg$ [49/50/51 ... people came]
$\neg$ [48_{gran1} people came] **does not entail** $\neg$ [50_{gran10} people came]

In other words, if negation intervenes *mo* and a number, where a small reading obtains, the round vs. non-round contrast results.

This analysis predicts that if a number does not have a contextually plausible round number, the negation may take a wider scope than numerals. This prediction is borne out as shown in (12):

(12) How many students came to your seminar?
3-nin-mo ko-nakat-ta yo.
3-CL-EVEN come-NEG-PAST
(lit.) "Even three students didn't come." (=Not even three students came.)

Extension to contrastive topic *wa* A similar contrast is observed when 50/48 is marked by contrastive topic marker *wa* (Ijima (1995)):

(13) {50/#48}-nin-wa kita
50/48-CL-CT came
"50/48 people came."

Following Sawada (2008), We assume contrastive topic *wa* has a flipped scalar presupposition of *mo*, as well as an anti-additive presupposition, as shown in (14):

(14) $[\![\text{wa}]\!]^{c,w} = \lambda p.\ p(w) = 1$, defined if
(i) $\forall p \in C.\ p \neq q \rightarrow p$ is more likely than q.
(ii) $\exists q \in C.\ p \neq q \wedge \neg q$

In this case, the affirmative is not allowed because 48_{gran1} has to be more likely than 50_{gran10}, which is not tenable.

(15) a. *wa*(50 people came) is defined if
(i) [50_{gran1} people came] is entailed by [51, 52, 53, ... people came].
(ii) It is possible that ¬[]51 (or 52, 53...) people came]

b. *wa*(48 people came) is defined if
(i) [48_{gran1} people came] is entailed by [49, 50, 51 . . . people came].
(ii) [48_{gran1} people came] is entailed by [50_{gran10} people came].
It is possible that ¬ [49, 50, 51 . . . people came].

Remaining issues The current analysis could also make a prediction about a construction with an overt approximator: with an overt approximator, *yaku/oyoso 50-mo* 'even about 50' still can be in the scope of negation. However, the only available interpretation is a reading where negation takes a narrower scope.

(16) Yaku/oyoso 50-nin-mo kita/ko-nakat-ta.
about 50-CL-mo came/come-NEG-PAST
(lit.) "Even about 50 people came/didn't come.' $*\neg >$ about 50, OK 50 $\neg$

Solt (2018) argues that an overt approximator is a PPI. Her explanation is based on the competition between a sentence with an overt approximator and a sentence with a bare number, and if the less simple version is used in negative context, it produces an implication contradictory to the assertion.

(17) Mary has/#doesn't have approximately/about 50 sheep.

If this analysis is on the right track, the competition between an overt approximator and a bare numeral still holds, which could lead to the PPI-hood of the former. We will discuss how our analysis may accommodate this insight.

Conclusion This paper discusses a peculiar behavior of numerals associated with focus particles with respect to polarity sensitivity. We show that the granularity of numerals has to be taken into consideration when alternatives are computed to satisfy the presupposition.

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Formalizing argument structures with Combinatory Categorial Grammar*

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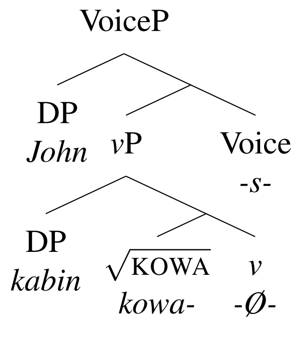
This study proposes a formalization of the *constructivist* analysis of argument structure, often couched in terms of Distributed Morphology (hereafter DM; Halle & Marantz, 1993), in Combinatory Categorial Grammar (hereafter CCG; Steedman, 2000). This formalization paves way for a model of incremental processing of argument structure based on constructivism. It also provides a novel account for the locality constraints on *contextual allomorphy*, which has been discussed extensively in the DM literature (Marantz, 2013a).

Most, if not all, analyses based on CCG encode the argument structure in the lexical entry of a verb. The Japanese verb *kowas-* 'break.transitive', for example, would have the category $S\backslash NP\backslash NP$ in such analyses. However, there is an alternative view on argument structure called *constructivism*, often couched in terms of DM (Marantz, 2013b). Constructivism assumes that argument structure is composed in the syntax, rather than in the lexicon. In (1), for example, the internal and external arguments are introduced by *v* and Voice, respectively. The root $\sqrt{\text{KOWA}}$ does not project any arguments. Constructivism is able to explain why verbs can be used in novel argument structures,[1] and why there is a systematic correspondence between syntactic positions and thematic roles (as formulated in UTAH (Baker, 1988)). These facts remain mysterious if argument structure is lexically specified.

(1) *John-ga kabin-o kowa-s-i-ta.* 'John broke the vase.'



*We thank the anonymous reviewers for helpful comments to the earlier version of this abstract.
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[1]An example of such novel argument structures is found in Clark and Clark (1979, p.803):

DM is suitable for constructivism since it captures both the hierarchical nature of argument structures and the irregularity of verbal morphology that reflects those structures. While the former is captured by the *single engine hypothesis* (Arad, 2003), the latter is captured by *late insertion*. Late insertion means the morphological (and semantic) realization of terminal nodes is determined after the syntactic structure is built and can refer to the syntactic context. In the Japanese sentence (1), for example, $\text{Voice}_{[+\text{D}]}$ is realized as *-s-* in the context of the root $\sqrt{\text{KOWA}}$ 'break'; the same head would be realized as *-e-* in the context of $\sqrt{\text{AK}}$ 'open' (Harley, 2008; Oseki, 2017). This analysis captures the fact that the transitivity morpheme in Japanese is separable from the root (cf. *kowa-re-* 'break.intransitive') but varies depending on the root.

While late insertion offers a nice account of contextual allomorphy, it is problematic when real-time use of language is taken into account since it presumes bottom-up structure building (cf. Bresnan & Kaplan, 1982). This is the primary motivation of our study: if we employ a surface-oriented grammar formalism that is compatible with incremental processing, how can we capture the constructivist nature of argument structure? Note that there is some psycholinguistic evidence that the decomposition of argument structure is relevant for real-time processing, not just for competence grammar (e.g., Friedmann et al., 2008).

This consideration led us to the formalization of the constructivist analysis in CCG, which is claimed to be compatible with incremental structure building (Steedman, 2000). Although most analyses in CCG are non-constructivist as mentioned earlier, we will demonstrate that the constructivist analysis can indeed be translated to CCG.

We focus on the Japanese verbal morphology as a test case since it has overt transitivity alternation morphology, as exemplified earlier. As a preparation for the constructivist analysis we first present an analysis of verbal inflection in Japanese. Our analysis is based on Bekki (2010) in many aspects, but decomposes moras into segments to draw a close parallel with the DM analysis. A caution should be paid that in a surface-oriented approach, morphophonological rewriting rules like *tob-da* 'fly-PAST' $\rightarrow$ *ton-da* cannot be assumed since a derivation must start from a string as it is observed. Instead, regularly alternating consonant like *b/n* in *tob-u* vs. *ton-da* must be separated from the nonalternating part as *inflectional consonant* (*Ic*), as shown below:[2]

(2) a.

$$
\dfrac{\dfrac{\dfrac{\text{to-}}{V_5^{stem}/Ic_b\backslash NP_{ga}} \quad \dfrac{\text{-b-}}{V_5^{stem}\backslash(V_5^{stem}/Ic_b)}}{V_5^{stem}\backslash NP_{ga}}{<}\mathbf{B} \quad \dfrac{\text{-u}}{S_{term|attr}\backslash V_5^{stem}}}{S_{term|attr}\backslash NP_{ga}}{<}\mathbf{B}
$$

(i) a. The factory horns *sirened* throughout the raid.
b. The factory horns *sirened* midday and everyone broke for lunch.
c. The police car *sirened* the Porsche to a stop.
d. The police car *sirened* up to the accident site.
e. The police car *sirened* the daylight out of me.

[2]We assume that the inflectional consonant is already type-raised as $V_5^{stem}\backslash(V_5^{stem}/Ic_b)$ in the lexicon, as shown in (2a), rather than having a simple category Ic_b and then being type-raised in the derivation. This follows the suggestion of one of the reviewers, who pointed out that the elimination of type-raising rules from the grammar has desirable consequences concerning parsing and long-distance dependency.

b.

$$\dfrac{\dfrac{\dfrac{\text{to-}}{V_5^{stem}/Ic_b\backslash NP_{ga}} \quad \dfrac{\text{-n-}}{V_{euph::d}\backslash(V_5^{stem}/Ic_{(b|m|n)})}}{V_{euph::d}\backslash NP_{ga}}{<}\mathbf{B} \quad \dfrac{\text{-da}}{S_{term|attr}\backslash V_{euph::d}}}{S_{term|attr}\backslash NP_{ga}}{<}\mathbf{B}$$

Once the analysis of inflection is established, we move on to the constructivist analysis of transitivity alternation (now with denotations):

(3)

$$\dfrac{\dfrac{\dfrac{\text{kowa-}}{\begin{array}{c}R_{vi}\\ \lambda e.kowa(e)\end{array}} \quad \dfrac{\text{-Ø-}}{\begin{array}{c}V_{base::[1]}\backslash NP\backslash R_{[1]}\\ \lambda P.\lambda x.\lambda e.P(e)\wedge theme(x)(e)\end{array}}}{\begin{array}{c}V_{base::vi}\backslash NP\\ \lambda x.\lambda e.kowa(e)\wedge theme(x)(e)\end{array}}{<} \quad \dfrac{\text{-s-}}{\begin{array}{c}V_{5::s}^{stem}\backslash NP\backslash V_{base::(v|vi|vii)}\\ \lambda P.\lambda x.\lambda e.P(e)\wedge causer(x)(e)\end{array}}}{\begin{array}{c}V_{5::s}^{stem}\backslash NP\backslash NP\\ \lambda x.\lambda y.\lambda e.kowa(e)\wedge theme(x)(e)\wedge causer(y)(e)\end{array}}{<}\mathbf{B}$$

This analysis exemplifies how contextual allomorphy can be treated in CCG, and provides further insights about the nature of allomorphy. The choice of the transitivity morpheme is based on the classification of the root (due to Jacobsen, 1992): *kowa-* belongs to class 6 (written *vi*). The class feature is inherited to the constituent *kowa-Ø-* by the variable [1]. The transitivity morpheme *-s-* then selects this feature, resulting in *kowa-Ø-s-*. Thus, in this analysis, contextual allomorphy is reduced to mere selection. The allomorphs should be listed in the lexicon, as shown below.

(4)
-s- $\vdash V^{stem}\backslash NP\backslash V_{base::(v|vi|vii)} : \lambda P.\lambda x.\lambda e.P(e)\wedge causer(x)(e)$
-as- $\vdash V^{stem}\backslash NP\backslash V_{base::(vii|ix|x)} : \lambda P.\lambda x.\lambda e.P(e)\wedge causer(x)(e)$
-os- $\vdash V^{stem}\backslash NP\backslash V_{base::xi} : \lambda P.\lambda x.\lambda e.P(e)\wedge causer(x)(e)$
$\vdots$

(4) has repeated appearances of the same denotation and similar categories. It is apparently less elegant than the DM analysis, where the denotation needs to be written only once (Voice$_{[+D]} \leftrightarrow \lambda P.\lambda x.\lambda e.P(e)\wedge causer(x)(e)$). Yet we can achieve the same level of abstraction in CCG as in DM by defining a function à la Bekki (2010) that maps class features to suffix forms, as shown in (5). Then the set of lexical items in (4) are defined succinctly as (6).

(5)
$$f(c) \stackrel{def}{=} \begin{cases} \text{-s-} & (c = v, vi, vii)\\ \text{-as-} & (c = viii, ix, x)\\ \text{-os-} & (c = xi)\\ \vdots & \end{cases}$$

(6) For any $c \in dom(f)$,
$f(c) \vdash V^{stem}\backslash NP\backslash V_{base::c} : \lambda P.\lambda x.\lambda e.P(e)\wedge causer(x)(e)$

Another, more interesting implication of the selection-based account of allomorphy concerns the locality constraints on the context for allomorphy. In the DM literature, it has been claimed that the choice of the allomorph to be inserted to a given terminal node is conditioned by its local context (Marantz, 2013a). Specifically, linear (string) and structural (semantic) adjacency seem relevant, although there are also cases where strict adjacency is not required (Merchant, 2015). The selection-based approach we consider here provides a natural explanation for these observations. In CCG, combinatory rules can be applied only for linearly adjacent elements (Principle of Adjacency; Steedman, 2000, p.54). The principle would predict that contextual allomorphy is only sensitive to linearly adjacent elements. But the feature inheritance mechanism we introduced earlier circumvents this principle without any limit: in a string *ABC*, if *B* selects *A* and inherits some of its features, and *C* selects *B*, then *C* is virtually sensitive to *A*'s features. Feature inheritance is not just for (3) but necessary to deal with any adjunctions (e.g., adverbials) that preserve the features of the target (e.g., agreement features on the verb). The real question is therefore how feature inheritance should be constrained. We propose a modified version of Principle of Categorial Type Transparency (Steedman, 2000, p.36):

(7) *The Principle of Categorial Type Transparency, revised*
For any constituent, the semantic type of its denotation, *the morphological class of its pronunciation,* and a number of language-specific directional parameter settings uniquely determine its category.

The intuition is that if *B* inherits features on *A*, they must be semantically or morphologically meaningful for the constituent *AB*. In the case of transitivity alternation (3), *kowa-Ø* is allowed to inherit the morphological class feature of *kowa-* since *-Ø-* is the identity element and thus *kowa-Ø* is indistinguishable from *kowa-*. Conversely, a morphologically visible element blocks inheritance of the morphological feature of the root. Thus, *huka-m-* 'deep-en,' *tuyo-m-* 'strength-en,' *taka-m-* 'height-en,' and so on, all show the same pattern of transitivity alternation (*-ar-/-e-*). If the feature in question is semantic rather than morphological, what is relevant is not the morphological visibility of the intervening element but rather the semantic congruity. This accounts for cases where contextual allomorphy is able to see a 'span' of nodes, defined in terms of extended projection, as discussed with Greek verbal conjugation by Merchant (2015).

As pointed out by both of our reviewers, a fundamental issue in constructivist analyses is how to constrain the set of argument structures that are allowed with a particular root. In the current framework, possible combinations of argument structures (i.e., argument-introducing items) and roots are defined by features that these items have. To capture the fact that *tabe-* 'eat', for example, can be combined with the phonologically null transitive morpheme but not with a pronounced transitive morpheme or an intransitive morpheme, one can assign to the root *tabe-* some feature(s) to be selected by the appropriate morpheme. One reviewer suggested that this would be just a 'notational variant' of the projectionist analysis, where *tabe-* is inherently specified as $V\backslash NP\backslash NP$. We believe the constructivist approach still has advantage over the projectionist one, since the decomposition captures the shared semantics between (i) alternating pairs such as *kowa-s-* and *kowa-re-*, and (ii) alternating and non-alternating (in)transitive verbs such as *kowa-s-* and *tabe-*.

In sum, we argue that a formalization of the constructivist analysis of argument structure in CCG, a grammar formalism compatible with incremental processing, is in fact possible, and even gives a natural explanation for why contextual allomorphy is subject to locality constraints that seem to resist simple characterization by linear or structural adjacency.

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Detecting modality and evidentiality:
Against purely temporal-aspectual analyses of the German semi-modal *drohen*

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Overview I argue that the semi-modal use of *drohen* `threaten' in German, which roughly means that something undesirable is going to happen, has a modal as well as an evidential component. In doing so, I argue against a purely temporal-aspectual analysis by Reis (2007), and more generally, against reductionist attempts to apply analyses for prospective aspect (e.g. Bohnemeyer 2014, Bowler 2018) to every future-oriented item. I propose a semantics of *drohen* which contains both modal and evidential components in a framework based on Mandelkern (2019) and Rullmann & Matthewson (2018).

Introduction The German verb *drohen* has a so-called semi-modal use, as is illustrated in (1). Syntactically, it takes an infinitival clause with *zu* placed in front of the infinitive verb, and semantically it can be roughly paraphrased as 'there is some sign that something undesirable is going to happen':

(1)	Das	Wetter	droht	schlechter	zu	werden.
	the	weather	DROH.PRES.3SG	worse	to	become.INF

'The weather threatens to become worse.'

Future orientation The time at which *drohen*'s prejacent is supposed to hold must be located after the evaluation time for the entire clause with *drohen*. This is shown by the infelicity of (2), which is intended to convey the present residence of Nicole:

(2) [I had expected that Nicole still lives in Amsterdam.]

#Aber	nun	droht	sie	auf einmal	in	Berlin	zu	wohnen.
but	now	DROH.PRES.3SG	she	suddenly	in	Berlin	to	live.INF

`#But now she suddenly threatens to live in Berlin.' [Adapted from Colomo (2011: 239)]

Based on *drohen*'s future-orientation and its syntactic affinity to aspectual verbs such as *anfangen* `begin', Reis (2007) argues for a purely temporal-aspectual analysis of *drohen* which involves reference to a phase preceding the prejacent eventuality (a "preparatory process" in Moens & Steedman's (1988) terms, which Bowler (2018) renames as "pre-state"). I call this kind of analysis a purely prospective analysis (PPA). Below I point out data which pose problems for PPAs.

Temporal-aspectual component alone is not enough. PPAs have difficulty with cases which involve negation scoping over *drohen.* Under the assumption that a prospective aspect operator denotes an existential quantifier over pre-states, as is proposed in recent formal analyses such as Bohnemeyer (2014) and Bowler (2018), PPAs would predict that the existence of a pre-state of the prejacent eventuality could be denied by negation and thus sentences with negated *drohen* are incompatible with contexts which entail the realization of the prejacent, because the realization of an eventuality implies the realization of its pre-state. However, this is not the case, as the felicity of (3) shows.

(3) Um 12:30 ist auf dem Marktplatz plötzlich ein Paket explodiert,
at 12:30 PERF.PRES on the market.place suddenly a packet explode.PP
obwohl bis zu diesem Zeitpunkt so etwas nie zu passieren gedroht hatte.
though till to this time such something never to happen DROH.PP PERF.PAST
`At 12:30 a package suddenly exploded in the marketplace, although until this time such a thing had never threatened to happen.'

Given this difficulty with the negation data, I rebut PPAs and argue for an alternative analysis which involves quantification over future times (relative to the evaluation time) but does not posit a prospective component, i.e., quantification over pre-states.

Detecting modality: *drohen*'s prejacent must be epistemically possible. *Drohen* in the present tense shows an epistemic-modal-like behavior in that it is incompatible with propositions which entail the negation of its prejacent, as (4) illustrates.

(4)#Der Damm droht unter den Fluten zu brechen, aber er hält stand.
The dam DROH.PRES.3SG under the floods to break but it holds stand
`#The dam threatens to burst under the floods, but it will hold.' [Colomo (2011: 241)]

The parallel to epistemic modals is sharpened by the observation that the same effect holds in embedded environments (cf. Yalcin 2007 for epistemic *might* and *must*):

(5)#Hans glaubt, dass es zu regnen droht,
Hans believes that it to rain.INF DROH.PRES.3SG
aber er glaubt auch, dass es nicht regnen wird.
but he believes also that it not rain.INF FUT.3SG
`#Hans believes that it threatens to rain, but he also believes that it won't.'

Furthermore, (6) shows that *drohen*'s modal force must be that of possibility: *drohen* can be used even when the context makes it explicit that the chance of the prejacent's holding true is very small.

(6) [Bennu is an asteroid which might collide with the earth in 2182. The probability of impact is calculated to be 0.037 percent.]
Bennu droht auf die Erde zu stürzen.
Bennu DROH.PRES.3SG onto the earth to crash
`Bennu threatens to crash to earth.'

(Retrieved from https://www.berliner-zeitung.de/news/studie-so-koennte-eine-atombombe-den-asteroiden-einschlag-verhindern-li.188246)

Taking also into the consideration the felicity of *drohen p* and *drohen q* (where *q* contextually entails *not p*), I conclude that *drohen* has an epistemic modal component whose modal force is that of possibility.

Detecting evidentiality: Epistemic possibility is still not enough. Given the data so far, it might seem that *drohen* is an epistemic possibility modal with future orientation. However, a further observation points to an evidential component in the semantics of *drohen*: even if there is a salient agent whose epistemic state is compatible with the prejacent being realized in the future, that alone does not suffice for her to assert a *drohen*-claim. This is illustrated by the infelicity of (7), where it is contextually established that Max entertains the possibility that the prejacent eventuality might happen but that there is no concrete evidence for that. In contrast, in a context differing from (7) only in that enough evidence for rainfall is established (e.g., dark clouds are quickly gathering over Max and the wind is picking up) the sentence becomes felicitous. This is explainable if the semantics of *drohen* requires the existence of some concrete evidence for the prejacent.

(7) [Context: Max is on the top of a mountain. Knowing that the weather in the mountains can change quickly, he entertains the possibility that it might rain soon, even though it is now completely cloudless and windless. He describes the situation as follows:]

#Es	droht	bald	zu	regnen.
it	DROH.PRES.3SG	soon	to	rain.INF

'It threatens to rain soon.'

Analysis In my analysis, the modal and evidential components in the semantics of *drohen* are captured as follows. For modality, to predict the incompatibility of *drohen* in the present tense (henceforth *droh.PRES*) with propositions implying the negation of its prejacent, I adapt Mandelkern's (2019) analysis of epistemic modals, which makes use of the notion of local context. It is represented as a parameter κ of the evaluation index, but unlike the original formulation, it is relativized to a time (see (8)), to capture the fact that *drohen* can be semantically tensed. *Drohen*'s modality amounts to existential quantification over a set of worlds which is obtained by applying the assignment function *g* to the subscript that *drohen* carries (k in (9)), a world *w*, and a time *t*, representing some salient individual's (typically, the speaker's) epistemic state at *t* and *w*. *Drohen*'s definedness condition requires that such states be subsets of the set determined by its local context (κ). Together with the truth-conditions of conjunction (10a), negation (10b), and attitudes like *glaub-*(*en*) '(to) believe' (10c), *droh.PRES p but not p* is predicted to be a contradiction, whether embedded or unembedded: the conjunction (10a) requires that each conjunct be interpreted with respect to a new information state function; it is almost the same as the original function (κ in (10a)), with the only difference that it maps a designated time in the index (t_0's in (10), which are by default identified with the time of context t_c) to a set of worlds where the other conjunct is true; Thus, as long as this designated time is used to evaluate *droh.PRES p but not p*, *droh.PRES p* must be interpreted with respect to a subset of an information state which supports the negation of the prejacent *p*, hence the contradiction. On the other hand, if some time other than the designated one in the index serves as an argument of the information state function, such a flow of information from the other conjunct does not occur. This captures a further observation that *drohen* in the past tense (*droh.PAST*), in contrast to *droh.PRES*, is compatible with the negation of its prejacent, as is illustrated by (11), where the second conjunct implies the negation of the prejacent of *droh.PAST* in the first conjunct (i.e., `The child did not drown.').

Second, *drohen*'s evidentiality is reflected in the metalanguage expression 'there is some concrete evidence' in the truth-condition (9b), which is intentionally left vague. Unlike Murray (2017), which also posits a primitive evidence relation in the semantics of evidentials, I do not posit an evidence holder, which is to cover cases with an unspecified evidence holder.

(8) κ is a function from a time to an information state (a set of worlds).

(9) For any world w, time t, and tenseless proposition P (a set of world-time pairs),
$[\![\text{drohen}_k]\!]^{g,\kappa}(w)(t)(P)$ is defined only if for any $w' \in \kappa(t)$: $g(k)(w')(t) \subseteq \kappa(t)$.
If defined, $[\![\text{drohen}_k]\!]^{g\,\kappa}(w)(t)(P) = 1$ iff
(a) there is some $w' \in g(\mathrm{k})(w)(t)$ such that there is some $t' > t$ such that $P(w')(t') = 1$ and
(b) there is some concrete evidence at w, t for P's holding true at some $t' > t$.

(10) For any world w, tensed clause p, and clause P whose tense is abstracted over:
a. $[\![\text{p und/aber q}]\!]^{g,t_c,t_0,\kappa}(w) = 1$ iff $[\![\text{p}]\!]^{g,t_c,t_0,\kappa^q_{g,t0}}(w) = 1$ and $[\![\text{q}]\!]^{g,t_c,t_0,\kappa^p_{g,t0}}(w) = 1$ where
for any world w and tensed clause φ, $\kappa^{\varphi}_{g,t0}(t_0) = \kappa(t_0) \cap \{w': [\![\varphi]\!]^{g,t_c,t_0,\kappa}(w') = 1\}$;
for any time t other than t_0, $\kappa^{\varphi}_{g,t0}(t) = \kappa(t)$.
b. $[\![\text{nicht p}]\!]^{g,t_c,t_0,\kappa}(w) = 1$ iff $[\![\text{p}]\!]^{g,t_c,t_0,\kappa}(w) = 0$.
c. $[\![\text{a glaub- P}]\!]^{g,t_c,t_0,\kappa}(w)(t) = 1$ iff for any world w' in $B_{a,w}(t)$, i.e., the set of worlds compatible with $[\![\text{a}]\!]^{g,t_c,t_0,\kappa}$'s belief at w, t, and any 'subjective now' t_1 of $[\![\text{a}]\!]^{g,t_c,t_0,\kappa}$ at w,t:
$[\![\text{P}]\!]^{g,t_c,t_1,B_{a,w}}(w')(t_1)$.

(11)	Ein	zweijähriges	Kind	drohte	zu	ertrinken,
	a	two-year-old	child	DROH.PST.3SG	to	drown
	wurde	aber	von	Badegästen	gerettet.	
	PASS.PST.3SG	but	by	bathers	rescued	

`A two-year-old child threatened to drown but was rescued by bathers.'

(Retrieved from https://www.westfalen-blatt.de/owl/kreis-herford/herford/herford-badegaste-retten-kind-2-im-freibad-vor-dem-ertrinken-2588193)

Given these entries, I will present a compositional analysis of clauses with *drohen* as an inflected element, based on Rullmann & Matthewson's (2018) framework for the tense-aspect-modality interaction, along the line shown in (12). Furthermore, I argue that *drohen*'s malefactive meaning (i.e. undesirability of the prejacent's realization) is to be treated in a separated dimension, using a multidimensional framework such as Gutzmann (2015).

(12) Es droht zu regnen. `It threatens to rain.' $\rightsquigarrow$ (drohen$_k$(PFV(it rain)))(PRES(t_i))

a. $[[\text{it rain}]]^{g,t_c,t_0,\kappa} = \lambda e.\lambda w.rain(e)(w)$

b. $[[\text{PFV}]]^{g,t_c,t_0,\kappa} = \lambda P.\lambda i.\lambda w.\exists e(\tau(e) \subseteq i \ \&\ P(e)(w))$

c. $[[\text{PRES}(t_i)]]^{g,t_c,t_0,\kappa} = g(\text{i})$ if $g(\text{i}) = t_c$; undefined otherwise.

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Cumulative reading, QUD, and maximal informativeness

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0. Overview. Sentence (1) has a distributive reading and a cumulative reading (see Brasoveanu 2013). This paper focuses on its **cumulative reading** and argues that **(i)** although cumulative reading involves multiple modified numerals, it does not involve multiple independent maximality operators, but only one, and **(ii)** this maximality operator is not mereology-based, but informativeness-based, with regard to a salient QUD.

(1) Exactly three^u boys saw exactly five$^\nu$ movies. Brasoveanu (2013)
Cumulative reading: The cardinality of all boys who saw any movies is 3, and the cardinality of all movies seen by any boys is 5.

1. Background. According to Brasoveanu (2013)'s account for the cumulative reading of (1), the semantic contribution of modified numerals, *exactly three* (*boys*) and *exactly five* (*movies*), is two-fold (or split, see also Bumford 2017): **(i)** First, (the indefinite component of) modified numerals introduce (plural) discourse referents (drefs), x and y; **(ii)** Then, after all the relevant restrictions, i.e., $\textsc{boy}(x)$, $\textsc{movie}(y)$, and $\textsc{see}(x,y)$, are added onto these drefs, (the definite component of) modified numerals impose maximality and cardinality tests, as delayed, post-suppositional evaluations (i.e., these tests are applied at a global sentential level, and in particular, after the restriction $\textsc{see}(x,y)$ is applied). The maximality tests pick out the maximal boy-sum and movie-sum, and the cardinality tests check the cardinalities of the maximal boy-sum and movie-sum (see (2)).

(2) $$[\![(1)]\!] \Leftrightarrow \underbrace{\sigma x \sigma y[\textsc{boy}(x) \wedge \textsc{movie}(y) \wedge \textsc{see}(x,y)]}_{\text{the mereologically maximal } x \text{ and } y \text{ satisfying these restrictions}} \wedge \underbrace{|y| = 5 \wedge |x| = 3}_{\text{cardinality tests}}$$
(σ: maximality operator; for notation simplicity, cumulative closure is assumed.)

Crucially, as pointed out by Brasoveanu (2013), the two maximality operators need to be applied **simultaneously** to guarantee that all 'boy-seeing-movie' events in the context are taken into consideration. Otherwise, the reading (3) would be derived. Intuitively, (1) is true in the context of Fig. 1, but false in the context of Fig. 2, indicating that the pseudo-cumulative reading in (3) (true for Fig. 2) is unattested and needs to be blocked.

(3) **Unattested pseudo-cumulative reading of (1)**:
$$\underbrace{\sigma x[\textsc{boy}(x) \wedge \underbrace{\sigma y[\textsc{movie}(y) \wedge \textsc{see}(x,y)]}_{\text{the mereologically maximal } y} \wedge |y| = 5]}_{\text{the mereologically maximal } x} \wedge |x| = 3$$
i.e., The maximal plural individual x satisfying the restrictions (i.e., atomic members of x are boys and each of them saw some movies, and x saw a total of 5 movies between them) has the cardinality of 3. $\rightsquigarrow$ **True** for Fig. 2! (see $b_2 \oplus b_3 \oplus b_4$ and $b_1 \oplus b_2 \oplus b_4$, and there is no larger boy-sum satisfying these restrictions.)

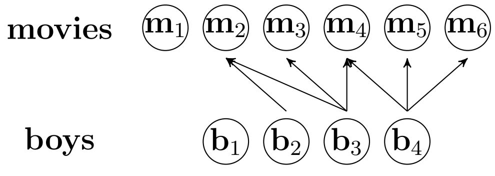

Figure 1: The genuine **cumulative** reading of (1) is **true** in this context.

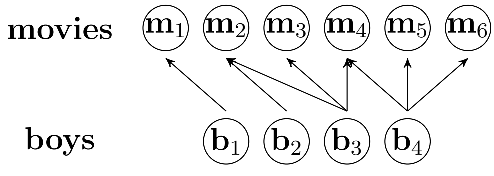

Figure 2: The genuine **cumulative** reading of (1) is **false** in this context.

2. An empirical challenge. As already pointed out by Krifka (1999), such a mereological-maximality-based analysis does not work for the case of (4). (4) is parallel with (1) in having a cumulative reading. However, Krifka (1999) argues that mereology-based maximality operators should pick out all land-owners and all the land, yielding an uninformative sentence like *In Guatemala, 100% of the population own 100% of the land*: 'What is peculiar with (4) is that it wants to give information about the bias of a statistical distribution . . . a picture of the skewing of the land distribution'. Evidently, this skewed picture is due to the contrast between a small part of population and a large part of land.

(4) In Guatemala, at most 3% of the population own at least 70% of the land.

Krifka (1999)'s discussion on (4) suggests that in accounting for the cumulative reading, (i) mereological maximality might only be a special case, and (ii) the multiple numerical expressions that together contribute to the cumulative reading should be inter-connected (see also Brasoveanu 2013's **simultaneity** in applying maximality operators).

3. Proposal. Obviously, sentences like (1) and (4) are used in different contexts, addressing different QUDs. Intuitively, (1) tells about an overall picture of film consumption among boys and can serve as a felicitous answer to questions like *how many boys saw how many movies*. Thus as analyzed by Brasoveanu (2013), when (1) is felicitously used, its interpretation is based on the cardinality measurement of the mereologically maximal relevant boy-sum and movie-sum (see the right-uppermost dot circled out in Fig. 3).

Then as argued by Krifka (1999), (4) addresses a degree QUD like *how skewed wealth distribution is in Guatemala*. Thus when (4) is felicitously used, its interpretation is based on the ratio between the percentage of owned land and the percentage of their owners in the population, and the extreme value of this ratio (or gradient) is achieved at the left-uppermost corner of the parallelogram (i.e., the point circled out) in Fig. 4.

The right-uppermost dot in Fig. 3 and the left-uppermost corner in Fig. 4 constitute extreme cases and represent maximal informativeness in addressing their respective QUD.

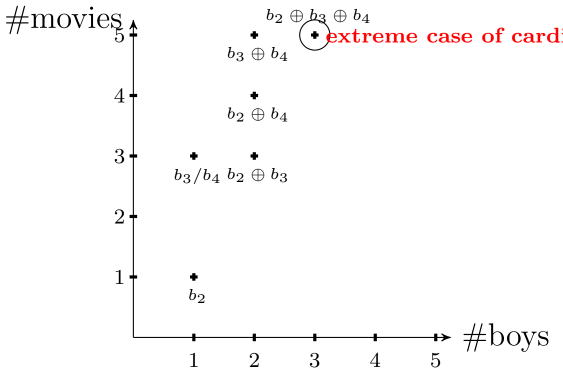

Figure 3: QUD: How much is the overall film consumption among boys? The cardinalities of some boy-sums and movie-sums in the context of Fig. 1 are plotted as dots.

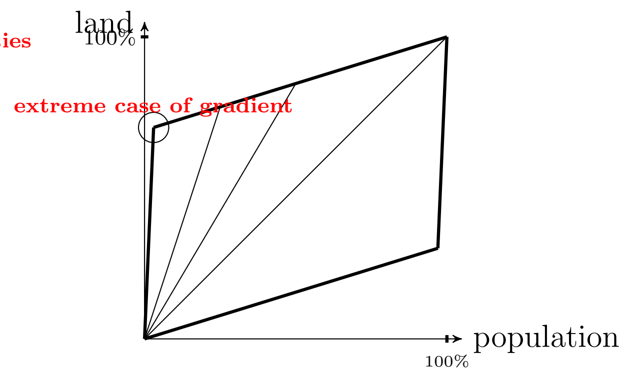

Figure 4: QUD: How skewed is wealth distribution in Guatemala? The percentages of the population and their owned land are within a parallelogram-like area.

Thus I propose a new **QUD-related, informativeness-based maximality operator** and implement it within a dynamics semantics framework:

(5) $\mathbf{M}_{u_1,u_2,\ldots} \overset{\text{def}}{=} \lambda m.\lambda g.\,\{h \in m(g) | \neg\exists h' \in m(g).\, G_{\text{QUD}}(h'(u_1,u_2,\ldots)) >_{\text{info}} G_{\text{QUD}}(h(u_1,u_2,\ldots))\}$
(Type of m: $g \to \{g\}$; Type of $\mathbf{M}$: $(g \to \{g\}) \to (g \to \{g\})$)

I assume meaning derivation to be a series of updates from an information state to another, and an information state is represented as a function from an input assignment function to an output set of assignment functions. As shown in (5), the operator $\mathbf{M}_{u_1,u_2,\ldots}$ works like a filter on information states. With the application of $\mathbf{M}_{u_1,u_2,\ldots}$, the discourse referents (drefs, which are assigned to $u_1, u_2, \ldots$) that lead to the maximal informativeness in resolving a QUD will be selected out. More specifically, to represent the resolution of a QUD, the operator G_{QUD} is applied on drefs and returns a value indicating informativeness. In this sense, G_{QUD} can be considered similar to a measurement function.

In addressing an overarching QUD like how high film consumption is among boys, higher informativeness means higher consumption (e.g., with $d_1 > d_2$, *the consumption level is d_1-high* entails (i.e., is more informative than) *the consumption level is d_2-high*). Thus the measurement of informativeness amounts to the measurement of cardinalities of plural drefs (see (6b)). Maximal informativeness is achieved when the mereologically maximal drefs (i.e., $b_2 \oplus b_3 \oplus b_4$ and $m_2 \oplus m_3 \oplus m_4 \oplus m_5 \oplus m_6$ in Fig. 1) are assigned (see (6c)). A step-by-step compositional analysis for (1) is thus shown in (6):

(6) a. $p = [\![\text{some}^u \text{ boys saw some}^\nu \text{ movies}]\!] = \lambda g.\left\{ g^{\substack{\nu\mapsto y\\ u\mapsto x}} \,\middle|\, \text{MOVIE}(y), \text{BOY}(x), \text{SAW}(x,y) \right\}$

b. $G_{\text{QUD}} = \lambda x.\lambda y.|x| + |y|$ (Simultaneously maximizing x and y is QUD-driven, not stipulated. cf. Brasoveanu 2013.)

c. $$\mathbf{M}_{u,\nu}(p) = \lambda g.\left\{ g^{\substack{\nu\mapsto y\\ u\mapsto x}} \,\middle|\, \begin{array}{l} y = \iota y.[\text{MOVIE}(y) \wedge \underbrace{\exists x[\text{BOY}(x) \wedge \text{SAW}(x,y)]}_{\text{some boys saw } y} \\ \wedge \underbrace{\forall y' \neq y[\text{MOVIE}(y') \wedge \exists x[\text{BOY}(x) \wedge \text{SAW}(x,y')] \rightarrow y' \sqsubset y]}_{y \text{ is mereologically maximal}}\ ] \\ x = \iota x.[\text{BOY}(x) \wedge \underbrace{\exists y[\text{MOVIE}(y) \wedge \text{SAW}(x,y)]}_{x \text{ saw some movies}} \\ \wedge \underbrace{\forall x' \neq x[\text{BOY}(x) \wedge \exists y[\text{MOVIE}(y) \wedge \text{SAW}(x,y)] \rightarrow x' \sqsubset x]}_{x \text{ is mereologically maximal}}\ ] \end{array} \right\}$$

d. $[\![(1)]\!] = [\![\text{exact } 3^u \text{ boys saw exactly } 5^\nu \text{ movies}]\!] =$
$$\lambda g.\left\{ g^{\substack{\nu\mapsto y\\ u\mapsto x}} \,\middle|\, \begin{array}{l} y = \iota y.[\text{MOVIE}(y) \wedge \exists x[\text{BOY}(x) \wedge \text{SAW}(x,y)] \\ \wedge \forall y' \neq y[\text{MOVIE}(y') \wedge \exists x[\text{BOY}(x) \wedge \text{SAW}(x,y')] \rightarrow y' \sqsubset y]\ ] \\ x = \iota x.[\text{BOY}(x) \wedge \exists y[\text{MOVIE}(y) \wedge \text{SAW}(x,y)] \\ \wedge \forall x' \neq x[\text{BOY}(x) \wedge \exists y[\text{MOVIE}(y) \wedge \text{SAW}(x,y)] \rightarrow x' \sqsubset x]\ ] \end{array} \right\}, \text{ if } \begin{array}{l} |x| = 3, \\ |y| = 5 \end{array}$$

In addressing how skewed wealth distribution is in Guatemala, higher informativeness corresponds to higher skewedness, which means higher gradient (see Fig. 4). Thus the measurement of informativeness amounts to the measurement of the ratio between the quantity of drefs (see (7b)). Maximal informativeness is achieved when the quantity of a dref y satisfying $\text{LAND}(y) \wedge \text{OWN}(x,y)$ divided by the quantity of a dref x satisfying $\text{HUMAN}(x) \wedge \text{OWN}(x,y)$ yields the maximal quotient (see (7c)). A step-by-step compositional analysis for (4) is thus shown in (7).

(7) a. $p = [\![\text{some}^u \text{ population own some}^\nu \text{ land}]\!]$
$= \lambda g.\left\{ g^{\substack{\nu\mapsto y\\ u\mapsto x}} \,\middle|\, \text{LAND}(y), \text{HUMAN}(x), \text{OWN}(x,y) \right\}$

b. $G_{\text{QUD}} = \lambda x.\lambda y.|y| \div |x|$

c. $\mathbf{M}_{u,\nu}(p) = \lambda g . \left\{ g^{\nu\mapsto y}_{u\mapsto x} \middle| \begin{array}{l} \langle x,y\rangle = \langle \iota x, \iota y\rangle \text{ such that } \textsc{land}(y) \wedge \textsc{human}(x) \wedge \textsc{own}(x,y) \\ \wedge\neg \underbrace{\exists y' \sqsupset y[\textsc{land}(y') \wedge \textsc{own}(x,y')]}_{y \text{ is the maximal land owned by } x} \\ \wedge \underbrace{\neg\exists x' \sqsupset x[\textsc{human}(x') \wedge \textsc{own}(x',y)}_{x \text{ is the maximal owner of } y}] \\ \wedge\forall x''\forall y''[\textsc{land}(y'') \wedge \textsc{human}(x'') \wedge \textsc{own}(x'',y'') \\ \wedge \underbrace{\neg\exists y''' \sqsupset y''[\textsc{land}(y''') \wedge \textsc{own}(x'',y''')]}_{y'' \text{ is the maximal land owned by } x''} \\ \wedge \underbrace{\neg\exists x''' \sqsupset x''[\textsc{human}(x''') \wedge \textsc{own}(x''',y'')]}_{x'' \text{ is the maximal owner of} y''} \rightarrow \frac{|y|}{|x|} \geq \frac{|y''|}{|x''|}] \end{array} \right\}$

d. $[\![(4)]\!] = [\![\text{at most } 3\%^u \text{ of the population own at least } 70\%^\nu \text{of the land}]\!] = \mathbf{M}_{u,\nu}(p)$, if $|x| \subseteq (0,3\%], |y| \subseteq [70\%,1]$

4. Discussion. Under the current analysis, it is the contextually salient QUD (i.e., what interlocutors care about, their ultimate motivation behind uttering sentences) that determines how informativeness is actually measured (see the implementation of G_{QUD} in (6b) vs. (7b)), which further determines how the informativeness-based maximality operator $\mathbf{M}_{u_1,u_2,\ldots}$ filters on drefs (before the evaluation of the quantity of selected drefs).

The notion of informativeness-based maximality proposed here is in the same spirit as but more generalized than the one proposed by Fintel et al. (2014) (which primarily aims to account for the interpretation of *the*; see also Schlenker 2012). According to Fintel et al. (2014), informativeness ordering is based on entailment relation (see (8)).

(8) Fintel et al. (2014)'s notion of informativeness ordering: For all x, y of type α and property ϕ of type $\langle s, \langle \alpha, t\rangle\rangle$, $x \geq_\phi y$ iff $\lambda w.\phi(w)(x)$ entails $\lambda w.\phi(w)(y)$.

Thus as shown in (9), depending on the monotonicity of properties, maximal informativeness corresponds to maximum or minimum values.

(9) a. For upward monotone properties, maximal informativeness means maximum values: e.g., given that $6 > 5.5$, *Mary is* $6'$ *tall* entails *Mary is* $5.5'$ *tall*.

b. For downward monotone properties, maximal informativeness means minimum values: e.g., given that $m > n$, *n walnuts are sufficient to make a pan of baklava* entails *m walnuts are sufficient to make a pan of baklava*.

Compared to Fintel et al. (2014), the notion of QUD-based maximal informativeness developed in the current paper is more generalized in two aspects.

First, in cumulative-reading sentences where multiple numerical expressions can be involved, maximal informativeness does not directly correspond to whether the uttered numbers are considered maximum or minimum values. In example (4), as observed by Krifka (1999), each of the numerical expressions (i.e., *at most 3%* and *at least 70%*) alone cannot be maximum or minimum values. It is how the combination of these uttered numbers contributes to resolve an implicit, underlying QUD that leads to the achievement of maximal informativeness.

Second, it is worth noting that under the scenario of Fig. 1, although *exactly 3 boys saw exactly 5 movies* holds true, *exactly 1 boy saw exactly 4 movies* does not hold true (in Fig. 1, no boys saw more than 3 movies). Thus, it seems problematic to build informativeness ordering directly upon the entailment relation between uttered sentences and their alternatives (here derived by replacing uttered numbers with other numbers).

However *exactly 3 boys saw exactly 5 movies* does indicate a higher film consumption (or a more prosperous situation) than the consumption level indicated by *exactly 1 boy saw exactly 4 movies*, i.e., the uttered sentence indicates a higher informativeness in addressing an underlying QUD than its alternatives. In this sense, by resorting to QUD, the current proposal provides a more generalized perspective on informativeness.

5. More empirical coverage. An anonymous reviewer asks whether, beyond cumulative-reading sentences, there are other cases where informativeness is determined by the immediate QUD rather than semantic entailment relation. Here is another case, which I have discussed in Zhang (2022). As shown in (10) (this example is from Szabolcsi 2017), under the given scenario, the use of an *even*-sentence is perfectly natural, but it challenges the traditional analysis of *even*. First, the presuppositional requirement of additivity is not met, because Eeyore was the only one who took a bite of thistles and spit them out. In other words, the truth of the prejacent does not entail the truth of alternatives like *X spit thistles out* (*X* is a member in the domain and different from Eeyore). Second, if no one other than Eeyore took a bite of thistles, it seems also questionable to claim that the likelihood of the truth of the prejacent is lower than that of *X spit thistles out*.

In Zhang (2022), I propose a new degree-QUD-based analysis for the presupposition of *even*. The use of *even* is always based on a contextually salient degree QUD (for (10), *how prickly are those thistles*). The prejacent of *even* (here *Eeyore spit those thistles out*) provides information to resolve this degree QUD with an increasingly positive answer, and compared with alternatives, this prejacent is also considered maximally informative in resolving this degree QUD (i.e., here *Eeyore spit the thistles out* is maximally informative in resolving the degree question *how prickly are those thistles*).

(10) **Scenario**: Imagine Pooh and friends coming upon a bush of thistles. Eeyore (known to favor thistles) takes a bite but spits it out.

  a. Those thistles must be really prickly! <u>Even [Eeyore]$_F$ spit them out!</u>
  ((10a) $\not\rightsquigarrow$ Someone other than Eeyore spit thistles out.)

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Language Politeness in Social Network

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Motivation

Language politeness (LP) has been an important topic in pragmatics. On the one hand, comparing to the non-politeness language form, the indirectness of LP brings more costs to the speaker. On the other hand, from Grice's theory of cooperate principle [2], interlocutors' behavior of LP can not be explained by Grice's theory.

The pioneer work of politeness theory is developed by Brown and Levison [1]. According to their politeness theory, politeness is a response to mitigate or avoid face-threatening acts such as request or insults. Therefore, for each interlocutor, using LP is a way to balance the imposition from raising a request and maintaining the relationship between the interlocutors. We call this explanation of LP as the strategic explanation. Many works have intended to formalize language politeness from the strategic point of view by models in game theory [11, 7, 13, 9].

On the other hand, contrary to the face-threatening theory, a lively area of politeness research concerns the conventional perspective of language politeness, which shades lights on the relationship between face and identity [10]. The honorific studies in Japanese language emphasize that language politeness is more of a relation-acknowledging device rather than the strategic behavior of saving faces [4]. In the Japanese culture, people are expected to act properly according to their relative position or rank with regard to other members of the group, and it is that relative position that they want to maintain when they employ politeness strategies.

Although the strategic and conventional explanation of LP have different focuses on either as an individual's LP behavior or a conventional behavior in a society, they both shade lights on the relationships between the interlocutors. By applying the social network theory [12, 3], we can easily represent the social distance (by using distances between agents) and the social power (by using the centrality notion in social network) between the interlocutors. Hence, Brown and Levison [1]'s three social variables (social distance, social power and imposition of a request) deciding the level of politeness can be modeled at the same time within the model of social network.

In addition, we can incorporate the conventional perspective of language politeness by considering an agents' behavior as a function of his neighbors. Considering all those factors, we construct a language game of LP with players located in a social network. Then, we use simulation studies to show how social structures affect the agents' use of language politeness.

A communication game of LP in Social Network (CLPS)

The CLPS is based on the communication game of language politeness in [6] with modifications.

Definition 1. *The communication game of language politeness in social networks (CLPS) consists of the following parts.*

1. *Players are located in a network $g = \{N, E_{ij}\}$ in which N is a set players, E_{ij} represents the edges between the players i, j;*

2. *At each time t, if agents i and j are connected in g, then i and j play the game twice, once i plays the role as the speaker and j be the hearer; and once j plays the role as the speaker and i be the hearer;*

3. *The social distance between the speaker i and the hearer j is denoted as $D_{ij} = d_{ij} + N_j^n$, in which d_{ij} represents the distance between two agents i and j in g. N_j^n represents the hearer j's number of neighbors within distance n in g, which characterizes the centrality of j in the network.*

4. *A social imposition s_{ij}^t for the speaker i and the hearer j at time t is defined as $s_{ij}^t = f^t(D_{ij} + r)$, which is a function of the social distance between the interlocutors and the imposition of a particular request r.*

5. *The speaker's action is to choose certain politeness $p \in R$, representing the language politeness.*

6. *The hearer's action is a function of the social imposition s given p, $P(s|p) \in [0, 1]$.*

7. *The player i's utility of choosing p is defined as $U_i(p) = EU_i - C(p)$, in which $EU_i = s_{ij}(D)P(s|p)$ and $C(p)$ is a linear function of p, representing the cost of using p.*

The model makes the following assumptions about the utility function.

1. The expected utility function $EU_S : R^+ \to R^+$ is supposed to be defined as a strictly monotonously increasing function with a decreasing slope;

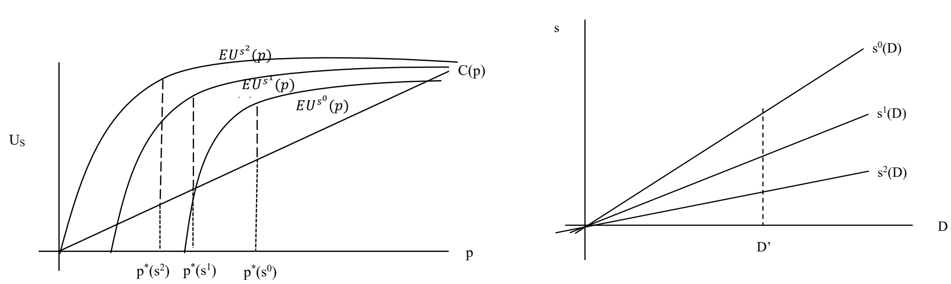
2. The cost function $C(p)$ is defined as a strictly monotonously increasing function with respect to the politeness p. [1]

An utility function that has such properties can be simply defined as

$$EU_S(p) = \begin{cases} (p-s)^{\frac{1}{2}} & \text{if } p > s; \\ 0, & \text{otherwise.} \end{cases}$$

$$C(p) = \beta \times p, \qquad \beta \in R^+$$

We use the following graphs to qualitatively describe the dynamics of the functions U_S, $s^t(D)$ and related parameters.



(a) dynamic of the utility

(b) dynamic of the social rates of imposition s^t when r=0

Figure 1

Figure 1(a) represents the dynamic of the speaker's utility function as the change of the politeness p and the social imposition s. It is obviously from the graph that as the social imposition

[1] Various works have shown that the indirectness and the length of the phrases are positively correlated to the politeness ([5, 8]). That is the main reason that we make this assumption here.

s decreases, the utility increases. The imposition of a request r is treated as a constant for each utility curve. p^* represents the optimal politeness for each utility curve. In Figure 1(b), we specify the dynamics of the social rate of imposition $s^t(D)$ as the times of communication t increases. Given any fixed D', the rates of imposition decreases. Without loss of generality, in the graph, we assume $r = 0$. For any fixed D', as communication enhanced, the social imposition decreases, i.e. $s^0(D') > s^1(D') > s^2(D')$.

The players are playing the game repeatedly. At each round of the game, every agent plays the LP game with the agents they are connected in the network. More specifically, each agent sends a request with respect to the social rate of the imposition s by sending a politeness phrase. After repeated plays of the game, we explore the change of agents' use of LP. In addition, we make two modeling rules for the dynamic of the game.

Rule 1 (Punishment Rule): If an agent k rejects agent i's (as a speaker) request, then agent i has a positive probability to reject k's request in the future.

Rule 2 (Dynamic Rule): The repetition of communication decreases the social rates of imposition for a fixed request and a fixed social distance between the interlocutors. At the same time, the speaker's utility is increasing as the rates of imposition s decreases.

Depending on whether we consider the strategic perspective or the conventional perspective of LP, we define two kinds of dynamics of the social imposition following Rule 2.

Dynamic 1(Strategic)

-
$$s_{ij}^0 = (D_{ij} + r)$$

-
$$s_{ij}^t(D) = \begin{cases} \dfrac{1}{U^{t-1}} * s_{ij}^{t-1}(D) & \text{if } U^{t-1} \geq 1; \\ (1 - U^{t-1}) * s_{ij}^{t-1}(D), & \text{otherwise.} \end{cases}$$

Dynamic 2 (Strategic + Conventional)

-
$$s_{ij}^0 = (D_{ij} + r)$$

-
$$s_{ij}^t(D) = \begin{cases} \omega(\dfrac{1}{U^{t-1}} s_{ij}^{t-1}(D)) + (1-\omega)\frac{1}{N_j}\sum_{k\in N_j^n} s_{kj}^{t-1} & \text{if } U^{t-1} \geq 1; \\ \omega((1 - U^{t-1}) s_{ij}^{t-1}(D) + (1-\omega)\frac{1}{N_j}\sum_{k\in N_j^n} s_{kj}^{t-1}, & \text{otherwise.} \end{cases}$$

in which $\omega \in [0, 1]$, The intuition for the second half of the formula is that the speaker is adopting the average of his neighbors' social impositions.

Regarding Rule 1 (Punishment rule), we explore two versions for the hearer's response.

Version 1: the hearer always responds positively to the speaker's request.

Version 2: the hearer responds positively with probability pr to the speaker's request, i.e. there is $(1 - pr)$ probability that $P(s|p) = 0$. Particularly, we assume that pr decreases as the distance d_{ij} increases. We use pr^1 represents the pr at the distance $d_{ij} = 1$.

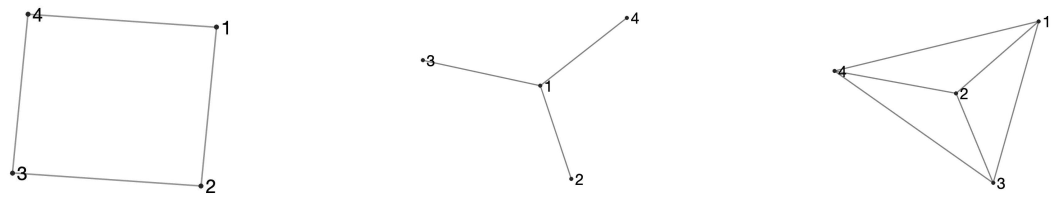
We do four simulations with the following combinations in Table 1.

	Dynamic 1 Strategic	**Dynamic 2** Strategic+Conventionl
Version 1 (always positive response)	Simulation 1	Simulation 2
Version 2 (randomly positive response)	Simulation 3	Simulation 4

Table 1

Simulation results

Three different networks (ring, star, complete) with four agents are applied in the simulations. Intuitively, the complete network characterizes the society or institute in which everyone is equally connected with respect to their distances and power differences. Hence, everyone in the complete structure has the same contribution or influence to the community. On the contrary, the star network represents the other extreme situation in which one person is the most powerful one (in terms of his centrality in the network), while other agents have the same importance in the structure. Intuitively, the star structure represents a relatively hierarchical society. Moreover, the ring structure represents a median situation with respect to the equality of the distance and the power difference among the three networks.



(a) Ring (b) Star (c) Complete

We list two comparative results with respect to four simulations mentioned in Table 1. The first result is to compare the degree of politeness through different networks with respect to each simulation (showing in Table 2).The second one is to compare different simulations within each network (showing in Figure 3). Overall, from all the simulations, we conclude the following observations.

(1) The level of politeness negatively correlates to the average of the utility.

(2) When the long distance communication has no cost, then the star shape network shows the least average politeness and the highest utility in terms of the use of LP; The complete network shows the highest level of politeness and the least average utility.

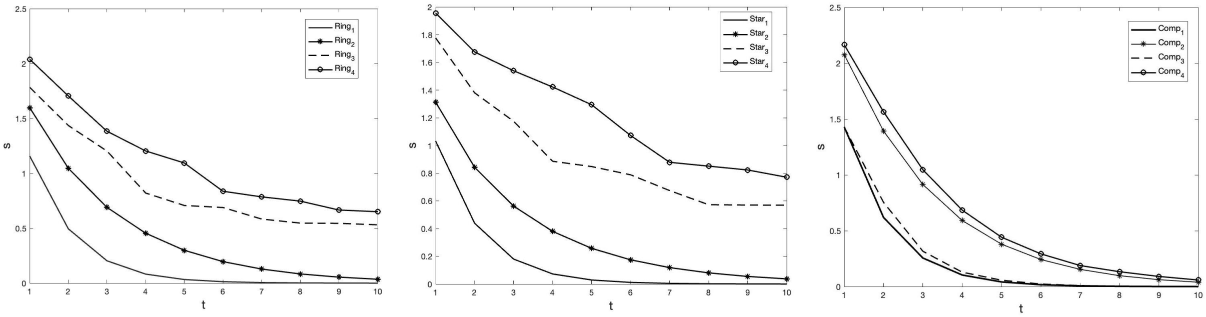
(3) When the long distance communication has a cost, i.e. long distance increases the failure of communication, then the complete network has the least LP and highest utility; while the star shape network shows the opposite features.

(4) The dynamic differences in the models (three simulations) only has effects on certain network. In the current result, only the complete network is sensitive to the dynamics. Other two networks have consistent comparative results through the four simulations.

Through the dynamic model within social networks, we can explore different quantitative features of using LP. The advantage of this method is that we can easily modify the model and extend the model to any kind of network structures.

	Ring	Star	Comp
Simulation 1 (strategic, positive response)	P^0 U^0	P^- U^+	P^+ U^-
Simulation 2 (strategic+conventional, positive response)	P^0 U^0	P^- U^+	P^+ U^-
Simulation 3 (strategic, random response)	P^0 U^0	P^+ U^-	P^- U^+
Simulation 4 (strategic+conventional, random response)	P^0 U^0	P^+ U^-	P^- U^+

Table 2: (P^- and P^+ means the least average politeness and the highest average politeness among the three networks. P^0 means the average politeness sits in the middle. U represents the average utility. Similar meanings are assumed by using U^+, U^- and U^0. Simulation results in this table are conducted by assuming $\omega = 0.5, pr^1 = 0.9, pr^2 = 0.1$)



(a) ring (b) star (c) complete

Figure 3: Comparison through simulations (‘Ring$_1$” in the figure means that simulation 1 conducted on the ring network, etc.)

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The Absence of NOR in Japanese

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1. Introduction

How we understand and express logical structure is a philosophically and linguistically important question. This paper tries to answer this question partly, focusing on the lexicalization of binary logical connectives in Japanese. Binary logical connectives are binary truth functions that take two propositions as input and assigns one proposition or truth value as output. As far as we concern Boolean truth values, there are 16 binary logical connectives including the conjunction operator $\wedge$ (or AND), the disjunction operator $\vee$ (or OR), and the logical equivalence operator $\leftrightarrow$ (or IFF). Henceforth, for the sake of simplicity of expression, I would call them "logical connectives" or "connectives."

The lexicalization of binary logical connectives has been studied from the point of view of both cross-linguistically and individual-liguistically (Horn, 1972, 2011; Katzir and Singh, 2013; Enguehard and Spector, 2021; Uegaki, 2022; a.o. for cross-linguistic studies: Mous, 2004; Bowler, 2015, for individual language studies.). These studies have rebealed that not all the connectives are lexicalizable in natural languages. Indeed, $NAND$ is never lexicalized in any natural language. Also, some of the previous studies show that inventories of lexicalized connectives vary among languages. For example, the inventory of logical connectives lexicalized in English is $\{AND, OR, NOR\}$ though that in Warlpiri is $\{OR\}$ (Bowler, 2015). However, no literature has discussed which connectives are lexicalized in Japanese. The system of logical vocabulary in Japanese is different from that of English. You can see it from the fact that there is no immediate translation for any of *and*, *or*, and *nor* in Japanese (cf. §§2, 3.2.1). Hence clarification of logical vocabularies in Japanese leads to a deeper understanding of Japanese semantics.

In this paper, I propose that the binary logical connectives that are lexicalized in Japanese are AND and OR. In the next section, we briefly observe that at least AND and OR are lexicalized in Japanese. After showing the minimum candidate for the inventory of Japanese logical connective items, I assert that no other logical connectives can be lexicalized in Japanese. Two facts support this argument: one is a consequence in the cross-linguistic studies that the maximum logical inventory lexicalizable in natural languages is $\{AND, OR, NOR\}$, and the other is a theoretical proof for the nonlexicalizability of NOR in Japanese. Lastly, I conclude this paper by overviewing the whole discussion and the future outlook of this research.

2. Lexicalization of AND and OR in Japanese

Although it is arduous to determine the perfect list of Japanese words corresponding to AND and OR, Japanese has obvious (pure) conjunction and disjunction items. As shown in (1-2), *katsu* corresponds to AND and *aruiwa* expresses OR [1] .

(1) Taro-ga hashiri katsu Hanako-ga arui-ta.
Taro-NOM run *katsu* Hanako-NOM walk-PAST
Taro ran or Hanako walked.

(2) Taro-ga hashit-ta-ka aruiwa Hanako-ga arui-ta.
Taro-NOM run-PAST-KA *aruiwa* Hanako-NOM walk-PAST

[1] *aruiwa* in (2) is optional though *ka* is necessary to express the disjunctive sentences. For this reason, one might say that *ka* is what expresses disjunction and *aruiwa* is only used to emphasize disjuctiveness. However, I assume here that *aruiwa* is the logical word because it is controversial whether *ka* is merely a disjunction operator (Uegaki, 2018). Whichever it is, the statement that Japanese has a lexical item corresponding to OR is true; hence the discussion does not essentially change.

Taro ran or Hanako walked.

Though slightly arguable, the particle *mo* is also an expression of AND in Japanese.

(3) Taro-mo Hanako-mo hashit-ta.
Taro-MO Hanako-MO run-PAST
Taro and Hanako ran.

The property *mo* has and *and* doesn't is that a single *mo* cannot create conjunctive sentence. It needs to appear as a pair as it does in (3). However, it is cross-linguistically prevalent that conjunction operators need to appear as a pair (Mitrović and Sauerland, 2014, 2016). Furthermore, sentences such as (3) do mean the conjunctive proposition in the absence of other logical-operator-like words, which is the most obvious reason that *mo* is one of the lexical items corresponding to AND.

3. NOR in Japanese

As we have seen in the previous section, AND and OR are lexicalized in Japanese. Thus, let $\mathcal{J}$ the set of all connectives that are lexicalized in Japanese and $\mathcal{C}$ the set of all connectives (i.e. $|\mathcal{C}| = 16$), we have ($*$):

($*$) $\{AND, OR\} \subseteq \mathcal{J} \subseteq \mathcal{C}$.

In this section, I try to give linguistic evidence that $\mathcal{J} = \{AND, OR\}$.

3.1. Universally unlexicalizable items

A number of studies have advocated that logical connectives beyond the Aristotelian square (i.e. connectives other than AND, OR, NOR, and $NAND$) and $NAND$ cannot be lexicalized in natural languages (Horn, 1972, 2011; Katzir and Singh, 2013; Carcassi and Sbarbolini, 2021; Enguehard and Spector, 2021; Uegaki, 2022; a.o.). Moreover, Carcassi and Sbarbolini (2021), Enguehard and Spector (2021), and Uegaki (2022) give independent accounts for the empirical fact that the inventories of logical connectives lexicalizable in a natural languages are only $\{AND, OR, NOR\}$, $\{AND, OR\}$, $\{AND\}$, and $\{OR\}$. These results allow us to strengthen the condition ($*$) to ($**$):

($**$) $\{AND, OR\} \subseteq \mathcal{J} \subseteq \{AND, OR, NOR\}$.

That is, at this point, the candidates for $\mathcal{J}$ are narrowed down to two inventories: $\{AND, OR\}$ and $\{AND, OR, NOR\}$.

3.2. Absence of NOR in Japanese

Then, the question is whether Japanese has a word for NOR or not. Simple observations suggest the negative answer to this question. A sentence which expresses a NOR proposition does not contain any specific word that only appears in sentences of NOR propositions.

(4) Taro-ga utai-mo odori-mo shi-nakat-ta.
Taro-NOM singing-MO dancing-MO do-NEG-PAST
Taro neither sang nor danced.

However, since the system of Japanese logical words is not simple, this mere observation does not confirm the absence of a lexical item with meaning of NOR in Japanese. It might be the case that there actually is a word corresponding to NOR, but that it is hard to identify the word just as no Japanese word is the immediate translation of *and*. Therefore, to conclude that $\mathcal{J} = \{AND, OR\}$, we need to prove that NOR is not lexicalized in Japanese. In the following subsections, I show that NOR is not lexicalizable in Japanese, which is sufficient for the proof for the nonexistence of the NOR item in Japanese.

3.2.1 How NOR is expressed in Japanese

As we have seen above, the most natural way to express NOR proposition is the negation of *mo*-conjunction sentence. Furthermore, Japanese sentences such as (4) can only be interpreted as NOR sentences. This is, I would argue that, the primary reason why NOR is not lexicalized in Japanese. On the contrary, the negation of a conjunctive sentence is ambiguous in two senses in English.

(5) Taro-ga utai-mo odori-mo shi-nakat-ta.
Taro-NOM singing-MO dancing-MO do-NEG-PAST

a. $\neg sing(Taro) \wedge \neg dance(Taro) \equiv sing(Taro)\ NOR\ dance(Taro)$

b. $^* \neg(sing(Taro) \wedge dance(Taro)) \equiv sing(Taro)\ NAND\ dance(Taro)$

(6) John did not dance and sing.

a. $\neg sing(John) \wedge \neg dance(John) \equiv sing(John)\ NOR\ dance(John)$

b. $\neg(sing(John) \wedge dance(John)) \equiv sing(John)\ NAND\ dance(John)$

This ambiguity in English leads to the necessity of a lexical item corresponding to NOR and the unambiguity in Japanese does not.

The unambiguity of the negation of *mo*-conjunction is supported by a theory if we admit a proposal by Mitroviċ and Sauerland(2014, 2016). According to them, there are two types of conjunctions. One conjoins two type t entities and the other conjoins two type $\langle e, t\rangle$ objects. English *and* is an example of the former and Japanese *mo* is the latter sort of conjucntion. Thier proposal is that latter sort of conjunctive items have the meaning shown in (7).

(7) $[\![mo]\!] \equiv \lambda S \lambda T. S \subseteq T$

Following this definition, the meaning of the sentence (5) is calculated as follows.

(8) $\neg do(Taro, \bigcap\{S|\{singing, dancing\} \subseteq S\})$

(8) cannot mean but that John did neither singing nor dancing, which is equivalent to NOR proposition. This is why (5b) is ungrammatical.

3.2.2 The informativeness/complexity trade-off model by Uegaki(2022)

Uegaki(2022) proposes an account for why only limited connectives are lexicalizable in natural languages. His proposal is based on the informativeness/complexity trade-off model, which is proposed by Kemp, et al. (2018) and succeeds in explaining the cross-linguistic pattern of lexicalization of several kinds of content words. If an inventory of concepts is lexicalizable, it is Pareto efficient concerning informativeness and complexity. According to Uegaki(2022)'s formulation, complexity indicates how simply the connectives in the inventory can be expressed only by $\neg$, $\wedge$, and $\vee$. The more blocks are needed to express a connective, the higher complexity it has, and vice versa. Informativeness is the summation of the degree of the likelihood that the use of the connective accurately conveys the speaker's intention under the scalar implicature. For example, the use of AND exactly expresses the possible world where the propositions coordinated by AND are both true, while the use of OR is ambiguous in that it cannot be determined which of disjuncts is true.

3.2.3 The formal definition of the informativeness

The complexity of an inventory of logical connectives does not vary among languages. However, the informativeness might change depending on languages. In this subsection, I modify the definition of the informativeness so that the grammar of individual language is reflected.

First, let me explain the formal definition of informativeness given by Uegaki(2022). Following Fox(2007), scalar implicature of a proposition is given as (9). Based on the definition (9), the scalar implicature of a logical connective is defined as (10). For example, let $L = \{AND, OR, NOR\}$ and for arbitrary propositions p and q, w_1 be the world where both are true, w_2 be the world where only p is true, w_3 be the world where only q is true, and w_4 be the world where neither is true. Then, $[\![L]\!] = \{\{w_1\}, \{w_1, w_2, w_3\}, \{w_4\}\}$, and $[\![OR]\!]^+_L = \{w_1, w_2, w_3\} \cap \{w_2, w_3, w_4\} \cap \{w_1, w_2, w_3\} = \{w_2, w_3\}$.

(9) a. $\text{ScalarImp}(p, A) := p \cap \bigcap\{\overline{p'} | p' \in \text{IE}(p, A)\}$

b. $\text{IE}(p, A) := \bigcap\{A' \subseteq A | A' \text{ is a maximal subset of A s.t. } p \cap \{\overline{p'} | p' \in A'\} \neq \emptyset\}$

(10) $[\![c]\!]^+_L := \text{ScalarImp}([\![c]\!], [\![L]\!])$,
where $[\![c]\!]$ is the set of worlds where the proposition $p\ c\ q$ is true and $[\![L]\!] := \{[\![c]\!] \mid c \in L\}$.

Utilizing the definition given by Steinert-Threlkeld(2019), he then gives the definition of informativeness I of an inventory of logical connectives L and the utility function u as follows. His calculation assumes that for every world w, the probability of the world $P(w) = \frac{1}{4}$. Also, it is assumed that $P(c|w) = \frac{1}{n}$ where $n = |\{c' \in L \mid w \in [\![c']\!]^+_L\}|$ if such c' exists (otherwise $P(c|w) := 0$) and $P(w|c) = \frac{1}{m}$ where $m = |[\![c]\!]^+_L|$ if $w \in [\![c]\!]^+_L$ (otherwise $P(w|c) := 0$).

(11) $I(L) := \sum_{w \in W} \left(P(w) \sum_{c \in L} \left(P(c|w) \sum_{w' \in W} P(w'|c) u(w, w')\right)\right)$

(12) $u(w, w') := \begin{cases} 1 & \text{if } w = w', \\ 0 & \text{otherwise.} \end{cases}$

As we have seen in the previous section, in some natural language, the negation of a connective might have a unique interpretation, depending on the grammar of the language. If a connective is uniquely represented in another way, there is no use to lexicalize the connective. This hypothesis can be realized by modification of utility function, using the set of grammatical connectives GC. The difference between (12) and (13) is that (13) excludes the case that lexicalization of a connective that can already be expressed by another (simple) expression has utility.

(13) Given an individual language $\mathcal{L}$,

a. $u^{\mathcal{L}}(w, w') := \begin{cases} 1 & \text{if } w = w' \text{ and } \{w\} \notin GC^{\mathcal{L}} \\ 0 & \text{otherwise,} \end{cases}$

b. $GC^{\mathcal{L}} := \left\{ [\![c]\!]^+_L \middle| \begin{array}{l} c \equiv c'\text{-}NEG \text{ or } c \equiv NEG\text{-}c' \text{ for some } c' \in L, \\ \text{and there is a unique expression of } c \text{ in } \mathcal{L} \end{array} \right\}$,
where $\phi\ NEG\text{-}c\ \psi \equiv (\neg\phi)\ c\ (\neg\psi)$ and $\phi\ c\text{-}NEG\ \psi \equiv \neg(\phi\ c\ \psi)$.

Replacing u in (11) with u', we finally can calculate the informativeness relativized to an individual language $\mathcal{L}$, which I denote by $I^{\mathcal{L}}$.

3.2.4 Application of $I^{\mathcal{L}}$ to Japanese

The purpose of defining the informativeness relative to a specific individual language was to prove the absence of NOR in Japanese. As I mentioned before, the candidates for $\mathcal{J}$ are $\{AND, OR\}$ and $\{AND, OR, NOR\}$. Thus, to determine the inventory lexicalized in Japanese, it is enough to calculate $I^{\mathcal{JPN}}(\{AND, OR\})$ and $I^{\mathcal{JPN}}(\{AND, OR, NOR\})$.

For the process of calculation, we first need to determine $GC^{\mathcal{JPN}}$. The observation I made in §3.2.1 confirms the following result. [2]

(14) $GC^{\mathcal{JPN}} = \{[\![NEG\text{-}AND]\!]^+_L\} = \{[\![NOR]\!]^+_L\}$

Following the definition in (9-14), we obtain the following result:

[2]Precisely speaking, what the observation in §3.2.1 verifies is no more than that $\{[\![NEG\text{-}AND]\!]^+_L\} \subseteq GC^{\mathcal{JPN}} \subseteq \{c\text{-}NEG | c = AND, OR, NOR\} \cup \{NEG\text{-}c | c = AND, OR, NOR\}$. However, it can be easily verified that whether $\{[\![NEG\text{-}AND]\!]^+_L\} \subsetneq GC^{\mathcal{JPN}}$ or not, $I^{\mathcal{JPN}}(\{AND, OR\}) = I^{\mathcal{JPN}}(\{AND, OR, NOR\})$; thus the same conclusion.

(15) a. $I^{\mathcal{JPN}}(\{AND, OR\}) = 0.5$. b. $I^{\mathcal{JPN}}(\{AND, OR, NOR\}) = 0.5$.

Since $I^{\mathcal{JPN}}(\{AND, OR\}) = I^{\mathcal{JPN}}(\{AND, OR, NOR\})$ and the complexity of $\{AND, OR, NOR\}$ is larger than that of $\{AND, OR\}$, the inventory $\{AND, OR, NOR\}$ is no more Pareto efficient. Therefore, $\{AND, OR\}$ is the only candidate for $\mathcal{J}$; that is, $\mathcal{J} = \{AND, OR\}$.

4. Conclusion

In this paper, I showed that the inventory of logical connectives lexicalized in Japanese, $\mathcal{J}$, is equal to $\{AND, OR\}$. First, $\{AND, OR\} \subseteq \mathcal{J}$ because *katsu* and *aruiwa* correspond to AND and OR. Then, $\mathcal{J} \subseteq \{AND, OR, NOR\}$ by the cross-linguistic regulation on lexicalization of connectives. Lastly, $\mathcal{J} \subseteq \{AND, OR\}$ is derived from the fact that NOR proposition is unambiguously expressed by the negation of *mo*-conjunction sentence in Japanese. The unambiguity of the negation of *mo*-conjunction sentence leads to the unnecessity of a lexical item corresponding to NOR. This process was formalized within the informativeness/complexity model, by relativizing the informativeness to Japanese. Therefore, the conclusion is that $\mathcal{J} = \{AND, OR\}$.

5. Future research

The idea of the informativeness relativized to an individual language can be trivially applied to other languages including Warlpiri and Iraqw, whose logical connectives are researched by Bowler(2015) and Mous(2004), respectively. If this idea accounts for all of those reported cases, it might lead to another theory of typology. That is, if two languages share the grammatical properties relevant to a specific domain of vocabulary, then the vocabulary of the domain should also be shared.

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End-to-End Compositional Modelling of Vector-Based Semantics

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Compositionality models the syntax-semantics interface as a structure-preserving map relating syntactic categories and derivations to their counterparts in a corresponding meaning algebra. In a categorial grammar, the syntactic categories take the form of types with a combinatorics governed by an appropriate type logic. The target meaning algebra for a distributional semantics has vector-based representations of word meanings obtained from data as its basic building blocks. An end-to-end view on compositionality here requires not only the elementary word embeddings to be obtained from data, but also the categories/types and their internal composition so that neural methods can then be applied to learn how the steps of a syntactic derivation can be systematically mapped to operations on the data-driven word representations.

In this talk, I report on the results of a five year project that aimed to realize such an end-to-end approach. The project focuses on Dutch data, but given that a categorial grammar essentially boils down to a type lexicon, its methods are readily adaptable to other languages. Key ingredients are an extended type logic that relies on the expressivity of categorial modalities to simultaneously capture dependency and function-argument structure; a geometry-aware approach to constructive supertagging that fully exploits the internal category structure, and a proofnet-based neural parser that associates raw text with programs for meaning assembly expressed as linear lambda terms. In all, the project highlights the benefits of a balanced neural-symbolic approach to NLP.

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Measurement Theory Meets Mereology in Multidimensionality in Resemblance Nominalism (Extended Abstract)

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1. Motivation

The *problem of particulars and universals* is one of the most essential problems in the *formal philosophy of language* in the sense that it consists in a crossroads of *ontology* and *semantics*: When we translate a natural language into a first-order (modal) language, (though it is a problem which formal language we should adopt in this translation), the *semantic problem* as to which entity we should choose as the semantic value of a symbol in the *model* of first-order modal logic depends crucially on the *ontological problem* as to which ontology we should adopt. According to Rodriguez-Pereyra (2015), there are at least two kinds of *Nominalism*: one that maintains that there are no *universals* and the other that maintains that there are no *abstract objects* like classes, functions, numbers and possible worlds. On the other hand, *Realism* about universals is the doctrine that there are universals, and *Platonism* about abstract objects is the doctrine that there are abstract objects. The doctrines about universals and the doctrines about abstract objects are *independent*. According to Rodriguez-Pereyra (2015), Nominalisms about universals can be classified into at least eight types: (I) Trope Theory, (II) Predicate Nominalism, (III) Concept Nominalism, (IV) Ostrich Nominalism, (V) Mereological Nominalism, (VI) Class Nominalism, (VII) Resemblance Nominalism, and (VIII) Causal Nominalism. Resemblance Nominalism in general is confronted with at least seven problems: (i) Imperfect Community Problem, (ii) Companionship Problem, (iii) Mere Intersections Problem, (iv) Contingent Coextension Problem, (v) Necessary Coextension Problem, (vi) Infinite Regress Problem, and (vii) Degree of Resemblance Problem. As Rodriguez-Pereyra (2015) argues, according to Resemblance Nominalism, it is not because things are scarlet that they resemble one another, but what makes them scarlet is that they resemble one another. Resemblance relations are *primitive* and the properties of a thing are *defined* by resemblance relations. Resemblance Nominalism reifies neither resemblance relations nor accessibility relations in themselves. Suzuki (2020) proposes, in terms of *measurement theory*, a first-order modal resemblance logic MRL that can furnish solutions to all of the problems (i)-(vii). Yi (2014) raises a version of degree of resemblance problem. Yi (2014, pp.622-625) argues as follows:

(1) Carmine resembles vermillion more than it resembles triangularity.

(2) is a resemblance-nominalistic formulation that expresses what makes (1) true:

(2) Some carmine particular resembles some vermillion particular more closely than any carmine particular resembles any triangular particular.

Rodriguez-Pereyra defines the *degree of resemblance* as follows (Rodriguez-Pereyra (2002, p.65)):

Definition 1 (Degree of Resemblance) *The particulars resemble to the degree n iff they share n sparse properties (About a sparse property, refer to Rodriguez-Pereyra (2002, pp.50-52).).*

Under Definition 1, (2) compares the *maximum* degrees of resemblance. But (2) is false because a possible carmine particular completely resembles a possible triangular particular. For the same particular might be both carmine and triangular. Rodriguez-Pereyra (2015) responses to Yi by replacing (2) by (3):

(3) Some carmine particular resembles some triangular particular less closely than any carmine particular resembles any vermillion particular.

Again under Definition 1, (3) compares the *minimum* degrees of resemblance. Rodriguez-Pereyra (2015, p.225) argues that (3) is true because the minimum degree to which a carmine particular can resemble a triangular particular (degree 0) is smaller than the minimum degree to which a carmine particular can resemble a vermillion particular (a degree greater than 0). Yi (2018, p.796) criticizes this Rodriguez-Pereyra's response by arguing that it rests on a false assumption: the minimum degree to which a carmine particular can resemble a vermillion particular is greater than 0. For, on *Rodriguez-Pereyra's* notion of resemblance, a carmine particular cannot resemble a vermillion particular unless they share a sparse property, but they might not share any such property. No doubt this argument by Yi needs examining in detail, but we can safely say that the main culprit of this Rodriguez-Pereyra-Yi Problem is Definition 1 on which both (2) and (3) are based. We consider this problem to be a problem of multidimensionality (such three dimensionality as carminity, vermillionity and triangularity) that requires *quantitative (numerical)* representations because we cannot have computational method of *aggregation* only in terms of qualitative resemblance relations. When we considered this problem, we realized that the model of MRL was not able to deal appropriately with the multidimensionality of this type of problem. The *aim* of this talk is to revise MRL so that the *revised first-order modal resemblance logic* RMRL can solve Rodriguez-Pereyra-Yi Problem in terms of measurement-theoretic multidimensional representation (cf. Suppes et al. (1989)). Measurement theory makes it possible that qualitative resemblance relations can represent quantitative (numerical) functions, whereas it is not designed to explicate the *parthood between a particular and its parts* (referred to for determining the raking on a resemblance relation). So, in the construction of the *multidimensional model* of RMRL, we would like to connect measurement-theory with *mereology* (cf. Varzi (2019)) that can explicate the *parthood between a particular and its parts* referred to for determining the raking on a resemblance relation. The punch line of Resemblance Nominalism is the *reducibility* of universals into resemblance relations. The point of *formalizing* Resemblance Nominalism in RMRL is to avoid the *circularity* in this reduction into which it tends to slide. In this talk, we try to give a solution to Rodriguez-Pereyra-Yi Problem by *defining* in RMRL the *degree of unresemblance* (*Definition 9*), instead of using Definition 1 (on which both (2) and (3) are based) that is the main culprit of this problem so that, in the multidimensional comparison of unresemblance of (1), the *weighted sum* of the degrees of unresemblance of carmine particulars to triangular particulars may be greater than that of carmine particulars to vermillion particulars. In so doing, RMRL obtains the capacity to deal with multidimensionality in general beyond Rodriguez-Pereyra-Yi Problem. In the semantics of RMRL, a resemblance relation is *primitive* and the degree of unresemblance is *defined* in Definition 9 by it via Representation Theorem (Theorem 1) and Uniqueness Theorem (Theorem 2).

2. Measurement Theory Meets Meleology in RMRL

We define the language $\mathscr{L}$ of revised first-order modal resemblance logic RMRL:

Definition 2 (Language) *Let $\mathscr{V}$ denote a class of individual variables, $\mathscr{C}$ a class of individual constants, and $\mathscr{P}$ a class of* one-place *predicate symbols. Let $\leqslant_F$ denote a* four-place resemblance predicate symbol *indexed by F. When $n \geq 2$, let $\leqslant_{F_1+\cdots+F_n}$ denote a four-place resemblance predicate symbol indexed by $F_1, \ldots, F_n$. The language $\mathscr{L}$ of* RMRL *is given by the following BNF grammar:*

$$t ::= x \mid a$$
$$\varphi ::= F(t) \mid t_1 = t_2 \mid \bot \mid \neg\varphi \mid \varphi \wedge \psi \mid (t_1, t_2) \leqslant_F (t_3, t_4) \mid (t_1, t_2) \leqslant_{F_1+\cdots+F_n} (t_3, t_4) \mid \Box\varphi \mid \forall x\varphi,$$

where $x \in \mathscr{V}$, $a \in \mathscr{C}$, and $F_1, \ldots, F_n \in \mathscr{P}$. $\top$, $\vee$, $\rightarrow$, $\leftrightarrow$, $<_F$, $<_{F_1+\cdots+F_n}$, $\Diamond$ and $\exists$ are introduced by the standard definitions. $(t_1, t_2) \leqslant_F (t_3, t_4)$ means that t_3 does not resemble t_4 more than t_1 resembles t_2 with respect to F-ness. *When $n \geq 2$, $(t_1, t_2) \leqslant_{F_1+\cdots+F_n} (t_3, t_4)$ means that t_3* does not resemble t_4 more than t_1 resembles t_2 with respect to F_1-ness and ... and F_n-ness. *The set of all well-formed formulae of $\mathscr{L}$ is denoted by $\Phi_{\mathscr{L}}$.*

Remark 1 (Modal Part of RMRL) *The modal part of* RMRL *is necessary only to solve (vi) Contingent Coextension and (v) Necessary Coextension Problems, and so does not directly relate to multidimensionality that is the main topic of this talk.*

Here we would like to introduce such measurement-theoretic concepts as *scale types*, *representation* and *uniqueness theorems*, and *measurement types* on which the argument of this talk is based. First, we classify *scale types* in terms of the class of *admissible transformations* φ. When φ is an *positive affine transformation*, we call a corresponding scale an *interval scale*. Second, we state about *representation* and *uniqueness theorems* that give a solution to two main problems with measurement theory: the *representation problem*: justifying the assignment of numbers to objects, and the *uniqueness problem*: specifying the transformation up to which this assignment is unique, respectively. THIRD, we classify *measurement types*. We call the representation $(\mathfrak{d}_1, \mathfrak{d}_2) \precsim (\mathfrak{d}_3, \mathfrak{d}_4)$ iff $|f(\mathfrak{d}_1) - f(\mathfrak{d}_2)| \leq |f(\mathfrak{d}_3) - f(\mathfrak{d}_4)|$, for any object $\mathfrak{d}_1, \mathfrak{d}_2, \mathfrak{d}_3, \mathfrak{d}_4$, *absolute difference measurement*. By using some measurement-theoretic concepts of Krantz et al. (1971) and Suppes et al. (1989), we prepare the following *six steps* to construct a model $\mathfrak{M}$ of RMRL: FIRST STEP: a step to prepare an *absolute difference* structure for the semantics of $\leqslant_F$ and $\leqslant_{F_1+\cdots+F_n}$. We resort to an *absolute difference structure* in order to solve the problems of Resemblance Nominalism. Krantz et al. (1971, pp.172-173) define an absolute difference structure:

Definition 3 (Absolute Difference Structure) *Suppose $\mathscr{D}$ is a nonempty class of objects and $\precsim$ a* quaternary relation *on $\mathscr{D}$. $(\mathscr{D}, \precsim)$ is an* absolute difference structure *iff the following six axioms are satisfied: Weak Order, Absoluteness, Betweenness, Weak Monotonicity, Solvability, and Archimedean Property defined in Krantz et al. (1971, pp.172-173) (Due to space limitations, we cannot describe the details.).*

We define a *property class* as a *maximal resemblance class* in terms of resemblance relation and absolute difference structure:

Definition 4 (Property Class) *$A \subsetneq \mathscr{D}$ is a* property class *iff $(\mathscr{D}, \precsim)$ is an absolute difference structure and for any $\mathfrak{d}_1, \mathfrak{d}_2, \mathfrak{d}_3 \in A$ and for any $\mathfrak{d}_4 \in \overline{A}$, $(\mathfrak{d}_1, \mathfrak{d}_2) \prec (\mathfrak{d}_3, \mathfrak{d}_4)$ (*Maximality*), where $(\mathfrak{d}_1, \mathfrak{d}_2) \prec (\mathfrak{d}_3, \mathfrak{d}_4) := (\mathfrak{d}_3, \mathfrak{d}_4) \not\precsim (\mathfrak{d}_1, \mathfrak{d}_2)$, for any $\mathfrak{d}_1, \mathfrak{d}_2, \mathfrak{d}_3, \mathfrak{d}_4 \in \mathscr{D}$.*

SECOND STEP: a step to prepare a basic *multidimensional* structure for $\leqslant_{F_1+\cdots+F_n}$. We prepare a basic multidimensional comparison structure, called a *factorial proximity structure*:

Definition 5 (Factorial Proximity Structure) *$(\mathscr{D}, \precsim)$ is a* proximity structure *iff the following conditions are satisfied for any $\mathfrak{d}_1, \mathfrak{d}_2 \in \mathscr{D}$: $\precsim$ is a* weak order. *$(\mathfrak{d}_1, \mathfrak{d}_1) \prec (\mathfrak{d}_1, \mathfrak{d}_2)$ whenever $\mathfrak{d}_1 \neq \mathfrak{d}_2$. $(\mathfrak{d}_1, \mathfrak{d}_1) \sim (\mathfrak{d}_2, \mathfrak{d}_2)$ (*Minimality*). $(\mathfrak{d}_1, \mathfrak{d}_2) \sim (\mathfrak{d}_2, \mathfrak{d}_1)$ (*Symmetricity*). The structure is called* factorial *iff $\mathscr{D} := \times_{i=1}^{n} \mathscr{D}_i$, where for any $\mathfrak{d}_i \in \mathscr{D}_i$ $(1 \leq i \leq n)$, an n-tuple $\mathfrak{d}_1 \cdots \mathfrak{d}_n \in \mathscr{D}$.*

THIRD STEP: In order to make each dimensional factor the *absolute* value of a scale *difference*, a factorial proximity structure $(\mathscr{D}, \precsim)$ should satisfy *Betweenness*, *Restricted Solvability*, and the *Archimedean Property* defined in Suppes et al. (1989, pp.180-181). FOURTH STEP: In order to represent the *sum* of dimensional factors, a factorial proximity structure $(\mathscr{D}, \precsim)$ should satisfy *Independence* and the *Thomsen Condition* only for the dimensionality $n = 2$.

Definition 6 (Additive Difference Factorial Proximity Structure) *When $n \geq 2$ and the* factorial proximity structure *$(\mathscr{D}(:= \times_{i=1}^{n} \mathscr{D}_i), \precsim)$ satisfies* Betweenness*,* Restricted Solvability*, the* Archimedean Property*,* Independence*, and the* Thomsen Condition *only for $n = 2$ defined in Suppes et al. (1989, pp.180-182), we call it an* additive difference factorial proximity structure.

FIFTH STEP: The ontological status of an n-tuple $\mathfrak{d}_1 \cdots \mathfrak{d}_n \in \mathscr{D}$ in Definition 5 is not clear. So in order to describe the *parthood between a particular and its parts* referred to for determining the raking on a resemblance relation, we would like to introduce *mereology*:

Definition 7 (Mereology) *A* mereological parthood function *P (Varzi (2019, p.14)) is a function from $\mathscr{D} \times \mathscr{D}$ to $\wp(\mathscr{D}^2)$ satisfying the following properties: For any $\mathfrak{d} \in \mathscr{D}$, $P(\mathfrak{d}, \mathfrak{d})$ (*Reflexivity*). For any $\mathfrak{d}_1, \mathfrak{d}_2, \mathfrak{d}_3 \in \mathscr{D}$, if $P(\mathfrak{d}_1, \mathfrak{d}_2)$ and $P(\mathfrak{d}_2, \mathfrak{d}_3)$, then $P(\mathfrak{d}_1, \mathfrak{d}_3)$ (*Transitivity*). For any $\mathfrak{d}_1, \mathfrak{d}_2 \in \mathscr{D}$, if $P(\mathfrak{d}_1, \mathfrak{d}_2)$ and $P(\mathfrak{d}_2, \mathfrak{d}_1)$, then $\mathfrak{d}_1$ equals $\mathfrak{d}_2$ (*Antisymmetry*). For any $\mathfrak{d}_1, \mathfrak{d}_2 \in \mathscr{D}$, a* mereological proper parthood function *$PP(\mathfrak{d}_1, \mathfrak{d}_2)$ is such a function that $P(\mathfrak{d}_1, \mathfrak{d}_2)$ and $\mathfrak{d}_1$ does not equal $\mathfrak{d}_2$. For any $\mathfrak{d}_1, \mathfrak{d}_2 \in \mathscr{D}$, a* mereological overlap function *$O(\mathfrak{d}_1, \mathfrak{d}_2)$ is such a function that there exists $\mathfrak{d}_3 \in \mathscr{D}$ such that $P(\mathfrak{d}_3, \mathfrak{d}_1)$ and $P(\mathfrak{d}_3, \mathfrak{d}_2)$. For any $\mathfrak{d}_1, \mathfrak{d}_2 \in \mathscr{D}$, if $PP(\mathfrak{d}_1, \mathfrak{d}_2)$, then there exists $\mathfrak{d}_3 \in \mathscr{D}$ such that $P(\mathfrak{d}_3, \mathfrak{d}_2)$ and not $O(\mathfrak{d}_3, \mathfrak{d}_1)$ (*Supplementation*) (Varzi (2019, pp.51-52)). For any $\mathfrak{d}_1, \mathfrak{d}_2, \mathfrak{d}_3 \in \mathscr{D}$, a* mereological product function *$S(\mathfrak{d}_3, \mathfrak{d}_1, \mathfrak{d}_2)$ is such a function that $P(\mathfrak{d}_4, \mathfrak{d}_3)$ iff $P(\mathfrak{d}_4, \mathfrak{d}_1)$ and $P(\mathfrak{d}_4, \mathfrak{d}_2)$, for any $\mathfrak{d}_4 \in \mathscr{D}$. For any $\mathfrak{d}_1, \mathfrak{d}_2 \in \mathscr{D}$, then there exists $\mathfrak{d}_3 \in \mathscr{D}$ such that $S(\mathfrak{d}_3, \mathfrak{d}_1, \mathfrak{d}_2)$ (*Product Existence*). For any $\mathfrak{d}_1, \mathfrak{d}_2 \in \mathscr{D}$, we define $\mathfrak{d}_1 \otimes \mathfrak{d}_2$ as the uniquely existential object bearing the relation S with $\mathfrak{d}_1$ and $\mathfrak{d}_2$, in symbols, $\iota\mathfrak{d}_3 S(\mathfrak{d}_3, \mathfrak{d}_1, \mathfrak{d}_2)$ (Varzi (2019, pp. 51-52).*

Final Step: By connecting *measurement-theoretic* concepts with *mereological* concepts, we define a *mereorogical additive difference factorial proximity structured model* $\mathfrak{M}$ of RMRL:

Definition 8 (Mereorogical Additive Difference Factorial Proximity Structured Model) *The* mereological additive difference factorial proximity structured frame *of* RMRL *is a structure* $\mathfrak{F} := (\mathscr{W}, R, \mathscr{D}, \{\precsim_F\}_{F \in \mathscr{P}}, \{\mathscr{D}_{\precsim_F}\}_{F \in \mathscr{P}}, P, \{\precsim_{F_1 + \cdots + F_n}\}_{F_1 \ldots, F_n \in \mathscr{P}})$*, where* $\mathscr{W}$ *is a non-empty class of worlds,* R *a binary accessibility relation on* $\mathscr{W}$*,* $\mathscr{D}$ *a non-empty class of particulars,* $\{\precsim_F\}_{F \in \mathscr{P}}$ *a non-empty class of such quaternary relations* $\precsim_F$ *on* $\mathscr{D}$ *that* $(\mathscr{D}, \precsim_F)$ *is an absolute difference structure and* $\precsim_F$ *satisfies* Maximality *of Definition 4,* $\{\mathscr{D}_{\precsim_F}\}_{F \in \mathscr{P}}$ *a non-empty class of* $\mathscr{D}_{\precsim_F}$ *which is a non-empty class of* the parts of particulars referred to for determining the ranking on $\precsim_F$ *and which postulates that there exists a unique object being a part of a particular belonging to* $\mathscr{D}$*,* P *a mereological parthood function from* $(\mathscr{D} \cup \bigcup_{F \in \mathscr{P}} \mathscr{D}_{\precsim_F}) \times (\mathscr{D} \cup \bigcup_{F \in \mathscr{P}} \mathscr{D}_{\precsim_F})$ *to* $\wp((\mathscr{D} \cup \bigcup_{F \in \mathscr{P}} \mathscr{D}_{\precsim_F})^2)$*,* $\{\precsim_{F_1 + \cdots + F_n}\}_{F_1 \ldots, F_n \in \mathscr{P}}$ *a non-empty class of such quaternary relations* $\precsim_{F_1 + \cdots + F_n}$ *on* $\mathscr{D}_{F_1 + \cdots + F_n}$ *defined as a non-empty class of such* $\bigotimes_{i=1}^n \mathfrak{d}_i$ *where* $\mathfrak{d}_i \in \mathscr{D}_{\precsim_{F_i}}$ $(1 \le i \le n)$ *that* $(\mathscr{D}_{F_1 + \cdots + F_n}, \precsim_{F_1 + \cdots + F_n})$ *is an additive difference factorial proximity structure. A function* I *is an* interpretation *of* $\mathfrak{F}$ *if* I *assigns to each* $a \in \mathscr{C}$ *and each* $w \in \mathscr{W}$ *some object that is a member of* $\mathscr{D}$ *that satisfies* Transworld Identity*: for any* w, w'*,* $I(a, w) = I(a, w')$*, and assigns to each four-place resemblance predicate symbol* $\leqslant_F$ *and each* $w \in \mathscr{W}$ *such a quaternary relation* $\precsim_F$*, and assigns to each four-place resemblance predicate symbol* $\leqslant_{F_1 + \cdots + F_n}$ *and each* $w \in \mathscr{W}$ *such a quaternary relation* $\precsim^*_{F_1 + \cdots + F_n}$ *that it is defined as follows: when, for any* $\mathfrak{d}_1, \mathfrak{d}_2, \mathfrak{d}_3, \mathfrak{d}_4 \in \mathscr{D}$*,* $\iota\mathfrak{d}_{i+4} P(\mathfrak{d}_{i+4}, \mathfrak{d}_1)$*,* $\iota\mathfrak{d}_{i+5} P(\mathfrak{d}_{i+5}, \mathfrak{d}_2)$*,* $\iota\mathfrak{d}_{i+6} P(\mathfrak{d}_{i+6}, \mathfrak{d}_3)$*,* $\iota\mathfrak{d}_{i+7} P(\mathfrak{d}_{i+7}, \mathfrak{d}_4) \in \mathscr{D}_{F_i}$ *are such uniquely existential objects that they satisfy* $P(\quad, \mathfrak{d}_1)$*,* $P(\quad, \mathfrak{d}_2)$*,*$P(\quad, \mathfrak{d}_3)$*,*$P(\quad, \mathfrak{d}_4)$ *respectively,* $(\mathfrak{d}_1, \mathfrak{d}_2) \precsim^*_{F_1 + \cdots + F_n} (\mathfrak{d}_3, \mathfrak{d}_4)$ *iff* $\bigotimes_{i=1}^n \iota\mathfrak{d}_{i+4} P(\mathfrak{d}_{i+4}, \mathfrak{d}_1), \bigotimes_{i=1}^n \iota\mathfrak{d}_{i+5} P(\mathfrak{d}_{i+5}, \mathfrak{d}_2)) \precsim_{F_1 + \cdots + F_n} (\bigotimes_{i=1}^n \iota\mathfrak{d}_{i+6} P(\mathfrak{d}_{i+6}, \mathfrak{d}_3), \bigotimes_{i=1}^n \iota\mathfrak{d}_{i+7} P(\mathfrak{d}_{i+7}, \mathfrak{d}_4))$*. By Definition 4, a* property class $I(F, w)$ *is defined as a* maximal resemblance class *in terms of a* resemblance relation $\precsim_F$*:* $A \subsetneq \mathscr{D}$ *is a* property class $I(F, w)$ *iff* $(\mathscr{D}, \precsim_F)$ *is an absolute difference structure and for any* $I(a, w), I(b, w), I(c, w) \in A$ *and for any* $I(d, w) \in \overline{A}$*,* $(I(a, w), I(b, w)) \prec_F (I(c, w), I(d, w))$*. The mereological additive difference factorial proximity structured model of* RMRL *is a structure* $\mathfrak{M} := (\mathscr{W}, R, \mathscr{D}, \{\precsim_F\}_{F \in \mathscr{P}}, \{\mathscr{D}_{\precsim_F}\}_{F \in \mathscr{P}}, P, \{\precsim_{F_1 + \cdots + F_n}\}_{F_1 \ldots, F_n \in \mathscr{P}}, I)$*.*

Remark 2 (Not Absoluteness But Conditionality) *The mereological additive difference factorial proximity structured model of* RMRL *does not require that* $\precsim_F$ *should absolutely satisfy such conditions above as Betweeness and the Archimedean Property and so on, but requires that* if $\precsim_F$ *satisfies them,* then *Theorems 1 and 2 below can be proven.*

Remark 3 (Nominalism about Universals) $\mathfrak{M}$ *is* nominalistic *both about such universals as properties and about* $\precsim_F$ *and* R neither *of which are* reified*, whereas it is* Platonistic *about such abstract objects as classes, functions, numbers and possible worlds. As Rodriguez-Pereyra (2015) observes, Realism/Nominalism about universals is* independent *of Platonism/Nominalism about abstract objects.*

Remark 4 (Non-Circularity of Resemblance Relation) *Since a resemblance relation* $\precsim_F$ *depends* not *on a* property class $I(F, w)$ *given by* $\precsim_F$ but *on a* predicate symbol F*, where* $I(F, w)$ *is the semantic value of* F*. In this sense,* $\precsim_F$ *is not circular.*

Remark 5 (Reducibility and Resemblance Nominalism) $\mathfrak{M}$ *is resemblance-nominalistic in the sense that* $I(F, w)$ *is* reducible *to* $\precsim_F$*.*

When an *assignment* s to $x \in \mathscr{V}$ is defined in such a way that the *extended assignment* $\tilde{s}$ agrees with I in the assignment to $a \in \mathscr{C}$, we can provide RMRL with the *satisfaction* definition relative to $\mathfrak{M}$ (i.e., $(\mathfrak{M}, w) \vDash \varphi[s]$), define the *truth* at a world in $\mathfrak{M}$ (i.e., $(\mathfrak{M}, w) \vDash \varphi$) by means of satisfaction, and then define *validity* (i.e., $\vDash \varphi$) (Due to space limitations, we cannot describe the details.). By Definition 8, we can prove the following *representation* and *uniqueness theorems* for $\precsim_{F_1 + \cdots + F_n}$ by modifying the proof method of Theorem 8 of Suppes et al. (1989, p.185):

Theorem 1 (Representation) *If* $(\mathscr{W}, R, \mathscr{D}, \{\precsim_F\}_{F \in \mathscr{P}}, \{\mathscr{D}_{\precsim_F}\}_{F \in \mathscr{P}}, P, \{\precsim_{F_1 + \cdots + F_n}\}_{F_1 \ldots, F_n \in \mathscr{P}}, I)$ *is a mereological additive difference factorial proximity structured model of* RMRL*, then there exist functions* $f_{\precsim_{F_i}} (1 \le i \le n) : \mathscr{D}_{\precsim_{F_i}} \to \mathbb{R}_{\ge 0}$ *and monotonically increasing functions* $g_{\precsim_{F_i}} (1 \le i \le n) : \mathbb{R}_{\ge 0} \to \mathbb{R}_{\ge 0}$ *such that for any* $\mathfrak{d}_1, \mathfrak{d}_2, \mathfrak{d}_3, \mathfrak{d}_4 \in \mathscr{D}$*,*$(\mathfrak{d}_1, \mathfrak{d}_2) \precsim^*_{F_1 + \cdots + F_n} (\mathfrak{d}_3, \mathfrak{d}_4)$

iff (4) $\sum_{i=1}^{n} g_{\precsim_{F_i}}(|f_{\precsim_{F_i}}(\imath\mathfrak{d}_{i+4}P(\mathfrak{d}_{i+4},\mathfrak{d}_1)) - f_{\precsim_{F_i}}(\imath\mathfrak{d}_{i+5}P(\mathfrak{d}_{i+5},\mathfrak{d}_2))|) \leq \sum_{i=1}^{n} g_{\precsim_{F_i}}(|f_{\precsim_{F_i}}(\imath\mathfrak{d}_{i+6}P(\mathfrak{d}_{i+6},\mathfrak{d}_3)) - f_{\precsim_{F_i}}(\imath\mathfrak{d}_{i+7}P(\mathfrak{d}_{i+7},\mathfrak{d}_4))|)$, *where* $\imath\mathfrak{d}_{i+4}P(\mathfrak{d}_{i+4},\mathfrak{d}_1), \imath\mathfrak{d}_{i+5}P(\mathfrak{d}_{i+5},\mathfrak{d}_2), \imath\mathfrak{d}_{i+6}P(\mathfrak{d}_{i+6},\mathfrak{d}_3), \imath\mathfrak{d}_{i+7}P(\mathfrak{d}_{i+7},\mathfrak{d}_4) \in \mathscr{D}_{\precsim_{F_i}}$.

Theorem 2 (Uniqueness) *The* $f_{\precsim_{F_i}}$ *are interval scales and the* $g_{\precsim_{F_i}}$ *are interval scales with a common unit.*

We define the degree of unresemblance and its weight in terms of Theorems 1 and 2:

Definition 9 (Degree of Unresemblance and Its Weight) *For any* $\mathfrak{d}_1, \mathfrak{d}_2 \in \mathscr{D}$, the degree of unresemblance *with respect to* $\precsim_{F_i}$ *is defined by* $|f_{\precsim_{F_i}}(\imath\mathfrak{d}_{i+4}P(\mathfrak{d}_{i+4},\mathfrak{d}_1)) - f_{\precsim_{F_i}}((\imath\mathfrak{d}_{i+5}P(\mathfrak{d}_{i+5},\mathfrak{d}_2))|$ *of (4), and its* weight *is defined by* $g_{\precsim_{F_i}}$ *of (4), where the existence and uniqueness of* $f_{\precsim_{F_i}}$ *and* $g_{\precsim_{F_i}}$ *are guaranteed by Theorems 1and 2 respectively.*

3. Conclusion

Suppose that $Cx := x$ is carmine, $Vx := x$ is vermillion, $Tx := x$ is triangular, and $(x,y) <_{C+V+T} (z,w) := x$ resembles y more than z resembles w with respect to carminity and vermillionity and triangularity. Then the RMRL-logical form of (1) is $\forall x \forall y \forall z((Cx \wedge Vy \wedge Tz) \to (x,y) <_{C+V+T} (x,z))$. Its semantic value (satisfaction condition) is given by the following proposition that follows from Theorem 1:

Proposition 1 (Solution to Rodriguez-Pereyra-Yi Problem by RMRL)
$(\mathfrak{M}, w) \models \forall x \forall y \forall z((Cx \wedge Vy \wedge Tz) \to (x,y) <_{C+V+T} (x,z))[s]$
iff there is no $\mathfrak{d}_1, \mathfrak{d}_2, \mathfrak{d}_3 \in \mathscr{D}$ *such that* $\mathfrak{d}_1 \in I(C,w)$ *and* $\mathfrak{d}_2 \in I(V,w)$ *and* $\mathfrak{d}_3 \in I(T,w)$ *and such that there exist* $f_{\precsim_C} : \mathscr{D}_{\precsim_C} \to \mathbb{R}_{\geq 0}$ *and* $f_{\precsim_V} : \mathscr{D}_{\precsim_V} \to \mathbb{R}_{\geq 0}$ *and* $f_{\precsim_T} : \mathscr{D}_{\precsim_T} \to \mathbb{R}_{\geq 0}$ *and* $g_{\precsim_C}, g_{\precsim_V}, g_{\precsim_T} : \mathbb{R}_{\geq 0} \to \mathbb{R}_{\geq 0}$ *such that* $(g_{\precsim_C}(|f_{\precsim_C}(\imath\mathfrak{d}_4P(\mathfrak{d}_4,\mathfrak{d}_1)) - f_{\precsim_C}(\imath\mathfrak{d}_5P(\mathfrak{d}_5,\mathfrak{d}_2))|) + g_{\precsim_V}(|f_{\precsim_V}(\imath\mathfrak{d}_6P(\mathfrak{d}_6,\mathfrak{d}_1)) - f_{\precsim_V}(\imath\mathfrak{d}_7P(\mathfrak{d}_7,\mathfrak{d}_2))|) + g_{\precsim_T}(|f_{\precsim_T}(\imath\mathfrak{d}_8P(\mathfrak{d}_8,\mathfrak{d}_1)) - f_{\precsim_T}(\imath\mathfrak{d}_9P(\mathfrak{d}_9,\mathfrak{d}_2))|)) \geq (g_{\precsim_C}(|f_{\precsim_C}(\imath\mathfrak{d}_4P(\mathfrak{d}_4,\mathfrak{d}_1)) - f_{\precsim_C}(\imath\mathfrak{d}_{10}P(\mathfrak{d}_{10},\mathfrak{d}_3))|) + g_{\precsim_V}(|f_{\precsim_V}(\imath\mathfrak{d}_6P(\mathfrak{d}_6,\mathfrak{d}_1)) - f_{\precsim_V}(\imath\mathfrak{d}_{11}P(\mathfrak{d}_{11},\mathfrak{d}_3))|) + g_{\precsim_T}(|f_{\precsim_R}(\imath\mathfrak{d}_8P(\mathfrak{d}_8,\mathfrak{d}_1)) - f_{\precsim_T}(\imath\mathfrak{d}_{12}P(\mathfrak{d}_{12},\mathfrak{d}_3))|))$.

We have the following conclusion: When we choose as the weight-assignment functions such functions $g_{\precsim_C}, g_{\precsim_V}, g_{\precsim_T}$ that the value of $g_{\precsim_T}$ is much greater than those of $g_{\precsim_C}$ and $g_{\precsim_V}$, Proposition 1 can give a solution to Rodriguez-Pereyra-Yi Problem by Definition 9 in terms of giving the satisfaction condition of (1) in RMRL so that the weighted sum of the degrees of unresemblance of carmine particulars to triangular particulars may be greater than that of carmine particulars to vermillion particulars, instead of using Definition 1 that is the main culprit of this problem. In so doing, RMRL obtains the capacity to deal with multidimensionality in general beyond Rodriguez-Pereyra-Yi Problem.

Acknowledgements
The author would like to thank two anonymous referees of LENLS19 for their very helpful comments.

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Extraction pathway marking as proof structure marking

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Data Extraction pathway marking is a phenomenon, exhibited by typologically diverse languages including Chamorro (Chung 1982), French (Kayne and Pollock 1978), Icelandic (Zaenen 1983) and Irish (McCloskey 1979), whereby the 'movement pathway' that establishes the linkage between the filler and the gap site is marked morpho-syntactically. The relevant data can be illustrated most clearly by the choice of different complementizers in Irish reported in McCloskey (1979). For expository convenience, we illustrate the relevant empirical patterns here by a pseudo-language called Iringlish, which is like Irish in having the relevant distinction of two complementizers but otherwise identical to English in all other respects.

In Iringlish, the complementizer *goN* is used when no extraction takes place:

(1) I thought **goN** [he would be there].

(2) I said **goN** [I thought **goN** [he would be there]].

Iringlish has another form of complementizer *aL*, which is restricted to clauses that contain an undischarged gap site inside itself (possibly in an embedded position):

(3) a. the man **aL** [__ would be there]
b. the man **aL** [I thought **aL** [__ would be there]]
c. the man **aL** [I said **aL** [I thought **aL** [__ would be there]]]

Note that, as shown in (4), a substructure inside a relative clause which itself doesn't contain an extraction pathway is marked by *goN*:

(4) the man **aL** [__ thought **goN** [he would be there]]

(4) shows that the *aL*/*goN* distinction cannot be analyzed as a surface constraint on complementizer choice which merely indicates whether the environment in question is 'inside' or 'outside' of a relative clause. Rather, the complementizer reflects the existence of an extraction gap inside the clause it marks.

In Iringlish, extraction pathway marking needs to be consistently encoded in all clause boundaries that are part of the extraction pathway. Thus, the following two examples are ungrammatical:

(5) a. *the man **aL** [I said **aL** [I thought **goN** [__ would be there]]]
b. *the man **goN** [I said **aL** [I thought **aL** [__ would be there]]]

In (5a), the lowest clause is marked by *goN* despite containing a gap. In (5b), the highest clause in the relative clause still contains an unbound gap to be matched with the filler (i.e., the head noun in the relative clause). In both cases, the right form is *aL*, and the string is ungrammatical.

Problem In Type-Logical Grammar, the linkage between the gap and the filler in long-distance dependencies is mediated by a general inference rule of hypothetical reasoning. In particular, in Hybrid Type-Logical Grammar (Hybrid TLG), which exploits prosodic lambda binding due to Oehrle (1994) in modelling both overt and covert 'movement' phenomena, extraction is modelled by a single chain of hypothetical reasoning. Specifically, Kubota and Levine (2020) utilize an operator which embeds an empty string in the gap position for the analysis of overt movement, building on an idea suggested in Muskens (2003). In this approach, (6) is analyzed as in (7).

(6) The guy who John thinks Mary said Bill criticized __.

(7)
$$
\begin{prooftree}
\AxiomC{$\mathrm{guy}; \mathbf{guy}; \mathrm{N}$}
\AxiomC{$[\varphi_0; x; \mathrm{NP}]^1$}
\noLine
\UnaryInfC{$\vdots$}
\UnaryInfC{$\mathrm{bill} \circ \mathrm{criticized} \circ \varphi_0; \mathbf{criticize}(x)(\mathbf{b}); \mathrm{S}$}
\AxiomC{$\mathrm{said}; \mathbf{say}; \mathrm{VP/S}$}
\BinaryInfC{$\mathrm{said} \circ \mathrm{bill} \circ \mathrm{criticized} \circ \varphi_0; \mathbf{say}(\mathbf{criticize}(x)(\mathbf{b})); \mathrm{VP}$}
\AxiomC{$\mathrm{mary}; \mathbf{m}; \mathrm{NP}$}
\BinaryInfC{$\mathrm{mary} \circ \mathrm{said} \circ \mathrm{bill} \circ \mathrm{criticized} \circ \varphi_0; \mathbf{say}(\mathbf{criticize}(x)(\mathbf{b}))(\mathbf{m}); \mathrm{S}$}
\AxiomC{$\mathrm{thinks}; \mathbf{think}; \mathrm{VP/S}$}
\BinaryInfC{$\mathrm{thinks} \circ \mathrm{mary} \circ \mathrm{said} \circ \mathrm{bill} \circ \mathrm{criticized} \circ \varphi_0; \mathbf{think}(\mathbf{say}(\mathbf{criticize}(x)(\mathbf{b}))(\mathbf{m})); \mathrm{VP}$}
\AxiomC{$\mathrm{john}; \mathbf{j}; \mathrm{NP}$}
\BinaryInfC{$\mathrm{john} \circ \mathrm{thinks} \circ \mathrm{mary} \circ \mathrm{said} \circ \mathrm{bill} \circ \mathrm{criticized} \circ \varphi_0; \mathbf{think}(\mathbf{say}(\mathbf{criticize}(x)(\mathbf{b}))(\mathbf{m}))(\mathbf{j}); \mathrm{S}$}
\LeftLabel{①$\to$}
\RightLabel{$\upharpoonright\mathrm{I}^1$}
\UnaryInfC{$\lambda\varphi_0.\mathrm{john} \circ \mathrm{thinks} \circ \mathrm{mary} \circ \mathrm{said} \circ \mathrm{bill} \circ \mathrm{criticized} \circ \varphi_0; \lambda x.\mathbf{think}(\mathbf{say}(\mathbf{criticize}(x)(\mathbf{b}))(\mathbf{m}))(\mathbf{j}); \mathrm{S}\upharpoonright\mathrm{NP}$}
\AxiomC{$\lambda\sigma.\mathrm{who} \circ \sigma(\epsilon); \lambda P\lambda Q\lambda u.\ Q(u) \wedge P(u); (\mathrm{N}\backslash\mathrm{N})\upharpoonright(\mathrm{S}\upharpoonright\mathrm{NP})$}
\BinaryInfC{$\mathrm{who} \circ \mathrm{john} \circ \mathrm{thinks} \circ \mathrm{mary} \circ \mathrm{said} \circ \mathrm{bill} \circ \mathrm{criticized} \circ \epsilon; \lambda Q\lambda Q(x) \wedge \mathbf{think}(\mathbf{say}(\mathbf{criticize}(x)(\mathbf{b}))(\mathbf{m}))(\mathbf{j}); \mathrm{N}\backslash\mathrm{N}$}
\BinaryInfC{$\mathrm{guy} \circ \mathrm{who} \circ \mathrm{john} \circ \mathrm{thinks} \circ \mathrm{mary} \circ \mathrm{said} \circ \mathrm{bill} \circ \mathrm{criticized} \circ \epsilon; \lambda x.\mathbf{guy}(x) \wedge \mathbf{think}(\mathbf{say}(\mathbf{criticize}(x)(\mathbf{b}))(\mathbf{m}))(\mathbf{j}); \mathrm{N}$}
\end{prooftree}
$$

Here, a relative clause is analyzed as a sentence missing an NP type gap, of type $\mathrm{S}\upharpoonright\mathrm{NP}$ (step ①), which is then given as an argument to the relative pronoun that has a higher-order semantics and prosody of the appropriate type to form a noun modifier of type $\mathrm{N}\backslash\mathrm{N}$. The process that derives a gapped sentence of type $\mathrm{S}\upharpoonright\mathrm{NP}$ is mediated by a general rule of hypothetical reasoning for the vertical slash $\upharpoonright$. A hypothesis of type NP is posited in the object position of the most deeply embedded verb, and this hypothesis is withdrawn at step ① to yield $\mathrm{S}\upharpoonright\mathrm{NP}$.

Crucially, in this analysis, the identification between the filler and the gap is mediated by a single chain of hypothetical reasoning. But this type of analysis seems to face a major challenge in view of the extraction pathway marking data reviewed above, since intermediate steps of derivation do not reflect the fact that extraction has ‘taken place’, unless one can directly inspect the structure of the proof tree. The two intermediate clauses are just plain S (and not $\mathrm{S}\upharpoonright\mathrm{NP}$) in this analysis, so, there is no way for the complementizer to ‘know’ that they contain a gap. The standard view in CG research dictates that derivations of linguistic signs just reflect the history of proof (of well-formedness of the derived sign), and that such proof histories are not real reified ‘objects’ that rules and constraints of the grammar can directly make reference to. But then, there is no obvious locus for the identification of the notion ‘connectivity pathway’. In fact, considerations of just this sort have led Kubota and Levine (2020) to propose an analysis which essentially simulates the ‘cyclic movement’ analysis in Transformational Grammar and the Principles and Parameters (P&P) framework (Kayne and Pollock 1978, among others) via a chain of hypothetical reasoning steps within a type-logical setup.

Solution We call into question the ban on making reference to structures of proofs, and propose a new analysis of extraction pathway marking in Hybrid TLG. The idea that derivation trees are not linguistic representations seems to stem from the tradition of Montague Grammar (where the idea that analysis trees do not have a similar status as syntactic trees in transformational grammar was repeated emphasized), and it was incorporated into the linguistic foundations of Type-Logical Grammar essentially as an unquestionable (or rather, unquestioned) given.

But once one starts looking outside of linguistics, one immediately notices that studying the structures of proofs formally is one of the central topics in the proof-theoretic/type-theoretic studies of formal logic including the Lambek calculus. In what follows, we show that an elegant and straightforward analysis of the extraction pathway marking patterns immediately becomes available once we incorporate a modest amount of technology from this literature into the underlying formal system of Hybrid TLG.

To facilitate the ensuing discussion, we introduce here an alternative notation of linguistic derivations in which a derivation/proof can be written as a proof term, building on the so-called Curry-Howard Isomorphism (Howard 1969). Essentially, one can establish a one-to-one correspondence between proofs and lambda terms by taking elimination steps to correspond to function application and introduction steps to correspond to lambda abstraction. Formally, this syntactic lambda calculus distinguishes three types of function application ($\mathrm{app}_/$, $\mathrm{app}_\backslash$, and $\mathrm{app}_\upharpoonright$), and three types of lambda abstraction ($\lambda_/$, $\lambda_\backslash$, and $\lambda_\upharpoonright$), corresponding to the three slashes in the underlying logic of Hybrid TLG.

As an illustration, consider the derivation (9) for (8).

(8) John read every book.

(9)
$$\dfrac{\dfrac{\begin{array}{l}\lambda\varphi_2\lambda\sigma.\sigma(\mathsf{every}\circ\varphi_2);\\ \lambda P.\mathbf{\forall}_P;\\ \mathrm{S}\upharpoonright(\mathrm{S}\upharpoonright\mathrm{NP})\upharpoonright\mathrm{N}\end{array} \quad \begin{array}{l}\mathsf{book};\\ \mathbf{book};\\ \mathrm{N}\end{array}}{\begin{array}{c}\lambda\sigma.\sigma(\mathsf{every}\circ\mathsf{book});\\ \mathbf{\forall}_{\mathbf{book}};\mathrm{S}\upharpoonright(\mathrm{S}\upharpoonright\mathrm{NP})\end{array}}{\upharpoonright}\mathrm{E} \quad \dfrac{\dfrac{\begin{array}{l}\mathsf{john};\\ \mathbf{j};\mathrm{NP}\end{array} \quad \dfrac{\mathsf{read};\mathbf{read};\mathrm{TV} \quad [\varphi_1;x;\mathrm{NP}]^1}{\mathsf{read}\circ\varphi_1;\mathbf{read}(x);\mathrm{VP}}/\mathrm{E}}{\mathsf{john}\circ\mathsf{read}\circ\varphi_1;\mathbf{read}(x)(\mathbf{j});\mathrm{S}}\backslash\mathrm{E}}{\lambda\varphi_1.\mathsf{john}\circ\mathsf{read}\circ\varphi_1;\lambda x.\mathbf{read}(x)(\mathbf{j});\mathrm{S}\upharpoonright\mathrm{NP}}{\upharpoonright}\mathrm{I}^1}{\mathsf{john}\circ\mathsf{read}\circ\mathsf{every}\circ\mathsf{book};\mathbf{\forall}_{\mathbf{book}}(\lambda x.\mathbf{read}(x)(\mathbf{j}));\mathrm{S}}{\upharpoonright}\mathrm{E}$$

The derivation in (9) can be rewritten as a proof term as in (10), with the lexicon in (11).[1]

(10) $\mathbf{EVERY}_{\mathrm{S}\upharpoonright(\mathrm{S}\upharpoonright\mathrm{NP})\upharpoonright\mathrm{N}}(\mathbf{BOOK}_{\mathrm{N}})(\lambda_\upharpoonright x.\mathbf{READ}_{\mathrm{TV}}(x_{\mathrm{NP}})(\mathbf{JOHN}_{\mathrm{NP}}))$

(11) $\mathbf{READ}_{\mathrm{TV}} = \mathsf{read};\mathbf{read};\mathrm{TV}$
$\mathbf{EVERY}_{\mathrm{S}\upharpoonright(\mathrm{S}\upharpoonright\mathrm{NP})\upharpoonright\mathrm{N}} = \lambda\varphi_2\lambda\sigma.\sigma(\mathsf{every}\circ\varphi_2);\lambda P.\mathbf{\forall}_P;\mathrm{S}\upharpoonright(\mathrm{S}\upharpoonright\mathrm{NP})\upharpoonright\mathrm{N}$
$\mathbf{JOHN}_{\mathrm{NP}} = \mathsf{john};\mathbf{j};\mathrm{NP}$
$\mathbf{BOOK}_{\mathrm{N}} = \mathsf{book};\mathbf{book};\mathrm{N}$

Note that Slash Elimination in (9) corresponds to function application in (10) and Slash Introduction in (9) corresponds to lambda abstraction in (10) (the types of application are not specified in (10) since they are all uniquely recoverable given the lexicon in (11)).

The proof term notation of derivations introduced above enables a concise formulation of the extraction pathway marking patterns exhibited by the Iringlish (or Irish) reviewed above. We illustrate this point with a fragment of Iringlish with the lexicon in (12).[2,3]

[1]Note that here, the variable x_{NP} is a variable in the syntactic logic and is thus unrelated to the x in the semantic component of the hypothesis in (9); we use the same variable letter only for expository ease.

[2]An anonymous reviewer for LENLS 2022 reminds us that the notion of 'only defined in' in (12) requires some comment. As noted by the reviewer, in a proof system, the well-formedness/typability of terms is usually defined via the typing rules that refer to the recursively specified formation rules for terms, and the side condition in (12) is not statable in terms of such typability conditions (which only look at local structures of terms). What we intend by the 'only defined in' clause in (12) is that, on top of the usual recursive specification of the purely formal well-formedness/typability conditions of proof terms in the logic, there is a separate filtering component for linguistically well-formed terms which inspects the forms of proof terms directly to determine whether they correspond to actual linguistic signs in the language. The point here is that the analysis of the phenomenon becomes much simpler if we assume this additional filtering component (whose technical formulation is trivial) rather than to encode its effect explicitly in the recursive typing definitions of terms.

[3]We assume that pronouns like *I* in (12) are (indexical) variables in the semantic component, but that at the level of syntactic proof terms they are constants. Thus, the presence of the pronoun in the embedded clauses in (13) does not affect the choice of the complementizers *aL* and *goN*.

(12) $\mathbf{WBT}_{\mathrm{NP\backslash S}}$ = would ∘ be ∘ there; $\lambda x.\mathbf{exist}(x, \mathbf{there})$; NP\S
$\mathbf{MAN}_{\mathrm{N}}$ = man; **man**; N
$\mathbf{I}_{\mathrm{NP}}$ = i; z_{sp}; NP
$\mathbf{THOUGHT}_{\mathrm{(NP\backslash S)/S'}}$ = thought; **thought**; $(\mathrm{NP}\backslash\mathrm{S})/\mathrm{S'}$
$\mathbf{SAID}_{\mathrm{(NP\backslash S)/S'}}$ = said; **said**; $(\mathrm{NP}\backslash\mathrm{S})/\mathrm{S'}$
$\mathbf{AL}_{\mathrm{S'/S}}$ = aL; $\lambda p.p$; $\mathrm{S'}/\mathrm{S}$ where for any α, $\mathbf{AL}(\alpha)$ is defined only if $\mathit{fv}_{\mathrm{X}_{+wh}}(\alpha) \neq \emptyset$
$\mathbf{GON}_{\mathrm{S'/S}}$ = goN; $\lambda p.p$; $\mathrm{S'}/\mathrm{S}$ where for any α, $\mathbf{GON}(\alpha)$ is defined only if $\mathit{fv}_{\mathrm{X}_{+wh}}(\alpha) = \emptyset$
$\mathbf{REL}_{\mathrm{(N\backslash N)\upharpoonright(S'\upharpoonright NP_{+wh})}}$ = $\lambda\sigma_2\lambda\varphi_2.\varphi_2 \circ \sigma_2(\epsilon)$; $\lambda P\lambda Q\lambda y.Q(y) \wedge P(y)$; $(\mathrm{N}\backslash\mathrm{N})\upharpoonright(\mathrm{S'}\upharpoonright\mathrm{NP}_{+wh})$

The key components of this analysis are the restrictions imposed on *aL* and *goN* that refer to the structures of the terms given as their (first) arguments. fv_{Φ} is the standard, inductively defined function that returns all free variables contained in a term, except that it filters the output of the general purpose *fv* to type Φ.

The derivation for (13) with the lexicon in (12) goes as in (14).

(13) the man **aL** [I said **aL** [I thought **aL** [__ would be there]]]

(14) $\mathbf{REL}_{\mathrm{(N\backslash N)\upharpoonright(S'\upharpoonright NP_{+wh})}}(\lambda_{\upharpoonright}x.\mathbf{AL}_{\mathrm{S'/S}}(\mathbf{SAID}_{\mathrm{(NP\backslash S)/S'}}$
$(\mathbf{AL}_{\mathrm{S'/S}}(\mathbf{THOUGHT}_{\mathrm{(NP\backslash S)/S'}}$
$(\mathbf{AL}_{\mathrm{S'/S}}(\mathbf{WBT}_{\mathrm{NP\backslash S}}(x_{\mathrm{NP}_{+wh}})))(\mathbf{I}_{\mathrm{NP}})))(\mathbf{I}_{\mathrm{NP}})))$

Note that each token of *aL* applies to a clausal complement containing a free NP_{+wh} variable.

(15) a. $\mathbf{AL}_{\mathrm{S'/S}}(\underline{\mathbf{WBT}_{\mathrm{NP\backslash S}}(x_{\mathrm{NP}_{+wh}})})$
b. $\mathbf{AL}_{\mathrm{S'/S}}(\underline{\mathbf{THOUGHT}_{\mathrm{(NP\backslash S)/S'}}(\mathbf{AL}_{\mathrm{S'/S}}(\mathbf{WBT}_{\mathrm{NP\backslash S}}(x_{\mathrm{NP}_{+wh}})))(\mathbf{I}_{\mathrm{NP}})})$
c. $\mathbf{AL}_{\mathrm{S'/S}}(\underline{\mathbf{SAID}_{\mathrm{(NP\backslash S)/S'}}(\mathbf{AL}_{\mathrm{S'/S}}(\mathbf{THOUGHT}_{\mathrm{(NP\backslash S)/S'}}(\mathbf{AL}_{\mathrm{S'/S}}(\mathbf{WBT}_{\mathrm{NP\backslash S}}(x_{\mathrm{NP}_{+wh}})))(\mathbf{I}_{\mathrm{NP}})))(\mathbf{I}_{\mathrm{NP}})})$

In each of these cases, $\mathit{fv}_{\mathrm{X}_{+wh}}(\alpha)$, where α is the underlined term, returns $\{x_{\mathrm{NP}_{+wh}}\}$.

The ungrammaticality of the examples in (5) also follows immediately in this approach. In the case of (5a), *goN* is used instead of *aL* in the subproof corresponding to (15a). This violates the constraint $\mathit{fv}_{\mathrm{X}_{+wh}}(\alpha) = \emptyset$ on the first argument of *goN*. Similarly, in (5b), *goN* replaces the first *aL* in the subproof corresponding to (15c). Here again, the relevant 'no unbound +*wh* hypothesis' constraint on *goN* is violated.[4]

It is important to note that extraction and apparently similar phenomena such as Right-node Raising are distinct, the former treated via the vertical slash $\upharpoonright$ in Hybrid TLG and the latter via the Lambek slash $/$. Support for such an assumption comes from the complementizer choices in Irish. To see this point, note the following examples from McCloskey (2011):

(16) a. Níor chualas **gur** leag nó **gur** mharaigh na tramanna
nior heard [S1] C-[PAST] knock-down or C-[PAST] kill the trams
duine ar bith ariamh.
person any ever

[4]A reviewer wonders whether an alternative, simpler analysis would be possible in which clauses containing a gap are distinguished from clauses that don't contain a gap in terms of the syntactic category. For example, the former could be S$\upharpoonright$NP and the latter could be S. This doesn't work in Type-Logical Grammar, since nothing forces intermediate S's to be analyzed as S$\upharpoonright$NP In which a long-distant linkage between the gap and the filler is mediated by a single instance of hypothetical reasoning as in (7). In order to make it obligatory that all intermediate gap-containing S's are analyzed as S$\upharpoonright$NP, some sort of additional constraint needs to be imposed. Kubota and Levine (2020) indeed opt for such a solution, using the clause-level indexing mechanism due to Pogodalla and Pompigne (2012) to simulate the 'cyclic movement' analysis in the P&P literature. A detailed comparison of this analysis and the present proposal which allows direct access to the structures of proof terms is beyond the scope of the present paper.

'I never heard that the trams ever knocked down or killed anyone.'

b. B'facthas dom **go** mbíodh, agus **go** bhfuil fós, na Beanna Arda mar phluid
seemed to-me that used-to-be and that are still the cliffs high like blanket
mhór thart orm.
great around on-me

'It seemed to me that the Great Cliffs had been and were still like a great blanket around me.'

The two conjoined clauses are of type $S/(TV\backslash S)$ in (16a) (and similarly for (16b)). Crucially, such expressions do not contain a free variable corresponding to the Right-node Raised expression in the syntactic proof term, since the Right-node Raised expression in question is already bound by $/$. Thus, our approach, together with independently motivated assumptions about Right-node Raising (see, e.g., Kubota and Levine (2020)), correctly predicts the occurrence of *goN* instead of *aL* in (16).

Discussion Our proposal boils down to the claim that extraction pathway marking falls out immediately as a linguistic marking of proof structure once we make one tiny step into the domain of proof theory. This of course comes at the price of breaking the dogma that proofs are not representational objects. But this move is worth making, for both technical and conceptual reasons. Technically, the step we have made is literally a tiny step, as it merely involves making reference to the notion of free variables in a typed lambda calculus, something that is already needed in formally interpreting lambda terms (for example, in the semantic domain).

Conceptually, our analysis of extraction pathway marking is arguably the simplest one among its competitors, but to see this point, we need to compare it with its major alternatives. Outside of categorial grammar, the consensus in the syntactic literature is that extraction pathway marking motivates a particular type of analysis of extraction in which the linkage between the filler and the gap is mediated by a chain of local dependencies: cyclic movement in P&P and the local inheritance of the SLASH feature in HPSG. These approaches have in common the property that they both explicitly encode the local chain of extraction pathway via some dedicated theoretical mechanism (such as a chain of locally restricted movement operations in P&P and the feature inheritance mechanism for the set-valued SLASH feature in HPSG).

Our analysis captures the same empirical patterns as these alternatives, but it differs from these more familiar proposals in that it involves nothing more than the independently needed formal modelling of gap inheritance via hypothetical reasoning. We think that the picture that emerges from this reconceptualization of extraction pathway marking is illuminating. Under this proof-theoretic perspective on the syntax of natural language, the phenomenon of extraction pathway marking is something that is naturally expected to be available in natural language, by making absolutely minimum assumptions about the nature of the extraction phenomenon itself.

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Constraining parse ambiguity with grammatical codes

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1 Introduction

This paper introduces a wide coverage "toolkit" for obtaining full parse analysis for English sentences. Parse results produced with the toolkit follow the annotation scheme of a grammatically analysed corpus, the Treebank Semantics Parsed Corpus (TSPC; Butler 2022). The primary goal for the toolkit has been to empower students who are medium to advanced learners of English to experience techniques of language analysis, and so acquire skills e.g., relevant for exploiting the online TSPC resource with its forty thousand trees of analysed data.

Originally the toolkit involved adding post-processing to statistical and neural based parser systems. This gave wide coverage and a way to manage ambiguity: rely on a "best" guess. However, this also gave unpredictable parsing errors, requiring students to be sensitive to miss-analysis. Also, these systems produce only a bare parse: There is no function information (e.g., subject), and there are no zero elements (e.g., relative clause traces). Attempts to add this information with post-processing were error prone in non-obvious ways, a task that essentially requires a full parse to do better! A further issue was that use of the original toolkit was simply too passive: There were no opportunities for students to influence the parse result with their own ideas about analysis.

These limitations motivated a re-orientation of the toolkit around a logic based grammar approach: The underlying automatic parser is now a Definite Clause Grammar (DCG; Pereira and Warren 1980) of the XSB Tabling Prolog system (Swift and Warren 2022).

A DCG consists of a Prolog program for parsing content given with a difference list as input. A DCG is written as phrase structure rules, possibly enhanced with extra logical parameters that can be used to accumulate structure from the parse or pass on other kinds of unifiable values such as selection criteria and records of long distance dependencies. The XSB implementation is particularly notable for allowing phrase structure rules to include left recursion without infinite loops arising from rule evaluation, achieved by remembering what was already evaluated with a technique called tabling.

The availability of this parsing engine creates new challenges: to increase grammar coverage for unconstrained English input, and more crucially to deal with proliferations of parse ambiguity.

Classroom experience suggests creation of word analysis is something students can do well. In contrast, creation of full parse structure is a major challenge. Partly this is a matter of familiarity: Students are already well drilled into identifying nouns, verbs, adjectives, and adverbs. But familiarity aside, creation of a full parse can remain a hard task that depends on a comprehensive understanding of language grammar and word interactions. There are also practical issues of dealing with a format for full parse representation.

The idea that is the focus of this paper is to unite the strengths of both human word analysis and an automatic system that creates structure from disambiguated word information. This paper is concerned with the word information that should be provided and the impacts of this information on subsequent depictions of derived analysis.

2 Utterance layers

To give an idea of how grammar rules are written, let's consider the utterance layer, which is the topmost structural layer of a parse. Prolog code (1) defines a phrase structure rule that will create a structure with `IP-MAT` (declarative matrix clause) as the topmost node.

(1)

```
utterance(Id,n(Id,IP,none)) -->
  clause_top_layer(statement,[],IPL-L1),
  punc(final,L1-[]),
  {
    IP =.. ['IP-MAT'|IPL]
  }.
```

To succeed, (1) needs content to parse from an input list of items where all but the last item satisfies a call of `clause_top_layer` with `statement` word order and no inherited displaced items (`[]`), and where the last list item will be an instance of final punctuation (identified with `punc`).

In (2), two Prolog calls are made. The first call has `tphrase_set_string` to establish a list of items to parse. The second call has `parse` to question whether the established parse list has content to satisfy an `utterance` rule with `'ex2'` to match `Id` of (1), while the second parameter for accumulating overall parse information is kept hidden internally to the `parse` call. If `parse` succeeds then all parse results are pretty printed as bracketed tree output.

(2)

```
| ?- tphrase_set_string(['PRO'('He'),'VBP;~I'(smiles),'PU'('.')]),
parse(utterance('ex2')).

( (IP-MAT (NP-SBJ (PRO He))
          (VBP;~I smiles)
          (PU .))
  (ID ex2))

yes
```

The pretty print from (2) shows the return of a structure with `IP-MAT` as the topmost node, from which it follows that rule (1) completed successfully.

As can be seen from rule (1), tree structure is built layer upon layer at parse time, with difference lists accumulating already built compound terms of the same layer. The difference list for a given layer is closed by the empty list (`[]`) and has the layer name added as the head list item to then be converted to a compound term with the univ operator, as in (3).

(3)

```
| ?- IP =.. ['IP-MAT','NP-SBJ'('PRO'('He')),'VBP;~I'(smiles),'PU'('.')].

IP = IP-MAT(NP-SBJ(PRO(He)),VBP;~I(smiles),PU(.))

yes
```

3 Motivating word analysis and the human touch

A word can only occur in contexts that are compatible for its contribution and this will in turn constrain the context available to other words of the same sentence and in this way much potential ambiguity is eliminated. Ambiguity surfaces when word analysis is not sufficiently sensitive to its context of occurrence and/or doesn't affect the contexts for other words.

Identifying word class significantly constrains potential ambiguity. Thus a noun can be either (i) the head word of a noun phrase or (ii) the modifier of a same level head word of a noun phrase. Identifying a word as a finite verb leads to the projection of a clause layer. With this background and with the word information of (4) (where `N`=noun, `VBD`=past tense lexical verb, and `PU`=punctuation), we might therefore expect the parse results of either (5) or (6).

(4) `Word_N word_N word_VBD ._PU`

```
(5)  (IP-MAT (NP-SBJ (N Word)
                     (N word))
             (VBD word)
             (PU .))
```

```
(6)  (IP-MAT (NP-109 (N Word))
             (NP-SBJ (N word))
             (VBD word)
             (NP-OB1 *ICH*-109)
             (PU .))
```

For (5), the first noun is a modifier of the second noun which heads a single noun phrase that is the clause subject. For (6), each noun is the head of its own noun phrase, with the first noun phrase a displaced item that is indexed linked to take object function, while the second noun phrase is the clause subject. Which parse needs to apply hinges on the selection requirements of the verb: if the verb is intransitive, then (5) is valid structure; if the verb is mono-transitive taking a noun phrase object, then (6) is valid structure.

The extra selection information of the verb can be given as a student oriented task with grammatical codes: `I`=intransitive verb, and `Tn`=mono-transitive verb with noun phrase object, so that (7) will unambiguously lead to the parse of (5), while (8) will unambiguously lead to the parse of (6).

(7) `Cheese_N pizza_N smells_VBD;~I ._PU`

(8) `Cheese_N pizza_N needs_VBD;~Tn ._PU`

4 Word class and grammar codes

The use of word class information and grammatical codes to feed parse analysis leads to the need for a system of word classes and a system of grammatical codes. The systems employed are both part of the annotation scheme for the TSPC, which in turn builds on word class analysis from BNC-Consortium (2005), and grammatical codes from Hornby (1975) and Cowie (1989).

The grammar code system is a cashing out of types of verb complementation found in English sentences, which are in turn associated with word sense definitions in Cowie (1989). For example, among its sense meanings, the verb *smell* can be a transitive verb with noun phrase object (code: `Tn`) with the word sense of (9), or it can be an intransitive verb and so lack complements (code: `I`) with the word sense of (10).

(9) [Tn] notice (sth/sb) by using the nose: Do you smell anything unusual?

(10) [I] have an unpleasant smell: Your breath smells.

Note how it is only word sense (10) that is compatible with (7) above.

5 Insight beyond the parse tree

While creating parse trees that conform to the TSPC annotation scheme is already revealing of language properties, there is opportunity to go further in regard to obtaining insight from analysis: The parse trees can be fed to the Treebank Semantics evaluation system (Butler 2021). This system can process (multiple) constituency tree annotations as input and return a logic-based meaning representation as output. As a recent development, it is now especially helpful to see created meaning representations as dependency graphs to make visually apparent connections that the design of the annotation captures in combination with the Treebank Semantics calculation.

As an example, consider word analysis for the minimal pair of (11) and (12), with differences hinging on the grammatical codes assigned to *was*.

(11) `The_D job_N was_BED;~equ_Vg cleaning_VAG;~Tn a_D dog_N ._PU`

(12) `The_D boy_N was_BED;~cat_Vg cleaning_VAG;~Tn a_D dog_N ._PU`

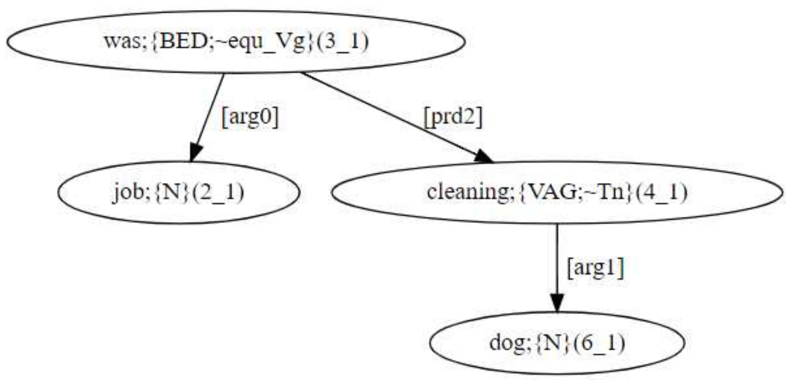
Differences are slightly magnified in terms of the labels of constituents resulting from the creation of parse trees, seen in (13) and (14), but the differences are hardly dramatic: Labels aside, the structural bracketing is identical.

```
(13)
(IP-MAT (NP-SBJ (D The)
                (N job))
        (BED;~equ_Vg was)
        (IP-PPL-PRD2 (VAG;~Tn cleaning)
                     (NP-OB1 (D a)
                             (N dog)))
        (PU .))
```

```
(14)
(IP-MAT (NP-SBJ (D The)
                (N boy))
        (BED;~cat_Vg was)
        (IP-PPL-CAT (VAG;~Tn cleaning)
                    (NP-OB1 (D a)
                            (N dog)))
        (PU .))
```

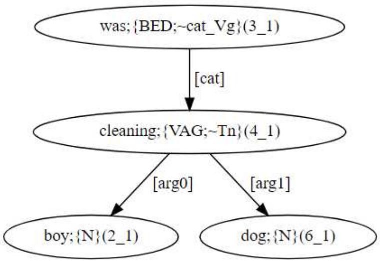
Yet differences are greatly magnified with the dependency analysis of (15) and (16).

(15)



The `equ_Vg` code marks *was* as an equative verb and so a main verb to establish equivalence of the subject (`arg0`) with the subject predicative (`prd2`) which has content made up of the present participle *cleaning* and its object (`arg1`) argument.

(16)



The `cat_Vg` code marks *was* as a catenative verb that provides past progressive aspect for the main verb which is the present participle as seen from the subject (`arg0`) linking.

6 Conclusion

To sum up, this paper proposes an approach for wide coverage parsing of English that involves phrase structure rules for a DCG parsing engine to build up parse information from rich word information. The rich word information is made with markers of word class and grammatical codes. Grammatical codes given to verbs double as partial indicators of word sense.

The word information can be supplied by students who are learning about grammatical analysis. This takes away the mundane crunching tasks of reaching parse analysis while leaving the task of providing the essential information (word class and grammatical codes) to determine the directions a parse takes. These are the really hard decisions of parsing that computers are still not very good at making, but this is exactly the information that humans excel at giving and are representative of in-depth insight into language competency, so skills language learners need to master. Also, ambiguity is not eliminated from parse results by some "best" guess. In fact, all results are returned, only with tree structure where spurious ambiguity is eliminated.

The use of human supplied codes gives similarity with discriminant-based treebanking (Oepen and Lonning 2006) or "bits of wisdom" (Basile et al. 2012) approaches that include human supplied constraints to guide wide coverage syntactic/semantic parsing. Arguably, the grammatical codes given to verbs considered in this paper are of special interest because they have an extra purpose too: They form information to disambiguate word sense linked to an existing dictionary resource. That is, the grammatical codes are themselves key insights into word sense that are independently of value for English language learners to know.

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In Search of a Type Theory for Fuzzy Properties

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1 Introduction

Types are a powerful language for describing properties. Over the past decades, researchers have used this aspect of types for diverse purposes, ranging from verification of compilers [14, 1], to representation of discourses [21, 2], and to formalization of music theory [24, 7]. These applications are all built on top of the *Curry-Howard isomorphism*, which relates types to propositions and programs to proofs.

Typically, whether an object satisfies a property is considered as a binary question. For instance, in the case of compiler verification, we say that a compiler is correct only if it is fully consistent with its specification. Such binary questions can be easily translated to a type inhabitation problem $e : \tau$, where e is a term representing the object we are interested in, and τ is a type encoding the property we would like e to satisfy.

On the other hand, there are cases where satisfaction of a property is not a binary question. As an example, in music composition, a choice of a note may be regarded better or worse than other choices, rather than absolutely good or bad. Such fuzzy properties require a type system with some form of *grades*, telling us to what extent an object satisfies a certain property.

In this abstract, we describe our work in progress on developing a type theory for expressing fuzzy properties. We begin by comparing three existing type systems with the notion of grades, designed for programming [3], linguistics [8], and music [6]. We then compare these systems to effect systems and coeffect systems, which allow grades-like annotations to appear in restricted places. It is our belief that a general theory of fuzzy properties will open up new possibilities of transferring knowledge between different areas.

2 Existing Type Systems with Grades

2.1 Precision Types

Boston et al. [3] implement *precision types* in the context of approximate computing, a technique for improving performance by allowing imprecise results. In their type system, types are annotated with a probability, representing how precise a value is. As an example, consider the `square` function below.

```
@Approx(0.8) int square(@Approx(0.9) int x) {
  @Approx(0.8) int xSquared = x * x;
  return xSquared;
}
```

In the signature of `square`, we state that the input `x` is precise with probability 0.9, and that we would like the output to be precise with probability 0.8. Assuming multiplication always produces a precise result, we can deduce that the product `xSquared` is precise with probability $0.9 \times 0.9 = 0.81$. This probability is greater than the expected probability 0.8, hence the function is judged well-typed. Thus, using the information of probabilities, we can soundly reason about the quality of a computation.

2.2 Probabilistic Type Theory

Cooper et al. [8] formulate a *probabilistic type theory* for natural language semantics, with a special focus on the modelling of human cognition and learning. In their framework, typing judgments may be associated with a probability, representing how likely a situation is true. For instance, in a situation where we have two strawberries, three red apples, and five oranges, we have the following judgments:

$$\begin{aligned} p(a : \text{Apple}) &= 0.3 \\ p(a : \text{Red}) &= 0.5 \\ p(a : \text{Apple} \mid a : \text{Red}) &= 0.6 \end{aligned}$$

The first judgment states that an object a is an apple with probability 0.3, and similarly, the second one states that a is red with probability 0.5. The last judgment states that a is an apple with probability 0.6 given that a is red. Using judgments like these, we can learn classifiers of situations and compute semantic values of sentences.

2.3 Weighted Refinement Types

Cong [6] proposes *weighted refinement types* as a means to formalize the rules of counterpoint, a style of composition where one composes a melody against another melody. In a weighted refinement type, every refinement predicate is paired with a weight, representing the reward one gets by choosing an interval satisfying that predicate. To illustrate this idea, we give a partial encoding of the rules for composing first-species counterpoint [10] as well as two example compositions.

```
CP : Type
CP = List (Pitch * Interval) < (isImperfect @ 30), (isDissonant @ -100) >

cp1 : CP @ 150
cp1 = [(c, per8), (d, maj6), (e, min6), (f, maj3),
       (e, min3), (d, maj6), (c, per8)]

cp2 : CP @ -10
cp2 = [(c, per8), (d, per5), (e, min3), (f, aug4),
       (e, min6), (d, maj6), (c, per8)]
```

The type `CP` defines counterpoint as a list of pitch-interval pairs refined by two predicates, each of which is coupled with a reward. The rewards encode the guidance that imperfect intervals (*i.e.*, thirds and sixths) are preferred and dissonant ones (*i.e.*, seconds, fourths, and sevenths) should be avoided. By summing up the rewards, we can discuss the theoretical correctness of counterpoint compositions. In the above example, `cp1` is considered more correct than `cp2` as it has more imperfect intervals and no dissonant ones.

3 Generalizing Existing Type Systems

We have seen three type systems that express fuzzy properties by means of grades. Now we turn to our research question: How can we design a general theory that subsumes these type systems? We do not have a concrete answer yet, but we conjecture that the resulting theory would share similarities with *effect systems* and *coeffect systems*.

Effect systems [16, 18] are a framework for tracking what side effect a program causes to the environment. Representative applications of effect systems include checked exceptions in Java, which prevent runtime errors, and the Cats Effect library of Scala, which guarantees resource safety of asynchronous programs. In an effect system, computation types or typing judgments carry an annotation, such as a set of exceptions and reading/writing actions. These annotations are similar to the precision on the output type of the `square` function from Section 2.1, and the probability on the judgments of situations from Section 2.2.

Dual to effect systems, coeffect systems [5, 20] are a framework for tracking what resource a program demands of the environment. Notable applications of coeffect systems include bounded variable use, where each variable can only be used a certain number of times, and secure information flow, where high-security data are guaranteed not to leak. In a coeffect system, variable bindings carry an annotation, such as the usage bound and security level. These annotations are similar to the precisions on the input types of the `square` function from Section 2.1.

There also exists a concept, called *graded modal types* [19], that allows simultaneous handling of effects and coeffects. In a system with graded modal types, computations and variable bindings may both carry an annotation, representing either a side effect or a resource demand. These annotations might subsume the three domain-specific annotations we saw in the previous section, including the rewards on refinement predicates we saw in Section 2.3 if we emulate refinement types as dependent pair types [23].

Once we have a uniform theory for fuzzy properties, we can explore opportunities to transfer techniques developed in one area to another area. For instance, in a type system that counts variable use, we can exploit the usage information to guide synthesis of programs [4]. By replacing variable use with probabilities, we could potentially extend this idea to perform proof search for sentences. As a different example, in a type system with probabilistic judgments, we can model incremental interpretation of utterances [12]. By viewing probabilities as rewards, we could possibly apply this idea to model incremental composition of music.

4 Related Work

The idea of grading types first appeared in the effect system of Lucassen and Gifford [16], which is designed for finding scheduling constraints of parallel computations. Since then, researchers have developed various graded type systems that enable fine-grained reasoning of programs [15, 22, 26], as well as techniques that make those systems usable in practice [25, 27].

In the context of natural language, grades have been used to give a compositional account of "linguistic effects", including anaphora resolution [11] and scope ambiguity [13]. We are however not aware of similar work on "linguistic coeffects", although there exist linguistic applications [9, 17] of a special case of coeffects (namely linear logic).

The recent years have also seen implementations of type systems with grades, such as Granule [19], Idris 2 [4], and Lambda VL [26]. These languages cannot currently express the three type systems discussed in Section 2, although their future versions may be able to do so by allowing the programmer to define custom grades.

5 Conclusion

We described our ongoing work on developing a general type theory for expressing fuzzy properties. As a first step toward this goal, we observed three type systems featuring grades and identified their similarities to effect and coeffect systems. We hope our work will stimulate interesting discussions across research communities and lead to better understanding of fuzzy phenomena.

Acknowledgments

The author is grateful to the anonymous reviewers for their encouraging comments. This work was supported by JST, ACT-X Grant Number JPMJAX210C, Japan.

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Logical Inference System with Text-to-Image Generation for Phrase Abduction

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1 Introduction

Recognizing Textual Entailment (RTE), that is, predicting whether a given premise sentence entails a hypothesis sentence, is regarded as a key task in Natural Language Processing (NLP) applications such as question answering and machine translation [6]. A variety of approaches to RTE have been proposed, including logical approaches [9, 10, 12, 19] and machine learning approaches [13, 14].

In this study, we focus on logical approaches, which succeed in obtaining semantic representations of sentences with linguistically challenging phenomena such as generalized quantifiers and comparatives. Logical approaches tend to achieve high precision (the number of correctly predicted entailment labels divided by the total number of predicted entailment labels) and low recall (the number of correctly predicted entailment labels divided by the total number of entailment labels in all premise–hypothesis pairs given to a system). However, logical inference systems cannot correctly predict entailment labels when the systems do not have the background knowledge necessary to prove that a premise entails a hypothesis. This is one of the main reasons for the low recall of such systems [3]. Previous logical inference systems [17, 25] have attempted to overcome this challenge by using knowledge databases such as WordNet [18] and the Paraphrase Database [7] to insert axioms as background knowledge during a proof. However, those systems still lacked the knowledge necessary for completing the proof.

Simultaneously, the recent development of deep learning has stimulated research on vision and language, including visual question answering [1], image captioning [11], and visual entailment [24]. Vu et al. [23] provided a visually grounded version of RTE problems. The work that is most closely related to ours is that by Han et al. [8]. They used visual denotations to acquire phrasal knowledge and combined this knowledge with textual and logic features from a logical inference system to provide an RTE classification model. However, they used a commercial API to retrieve images from limited image databases, which makes it difficult to obtain knowledge for arbitrary combinations of phrases.

In the present study, we aim to improve the performance of ccg2lambda[1] [16], a higher-order inference system that automatically conducts natural deduction proofs on compositional semantics of natural language based on Combinatory Categorial Grammar (CCG) [22] parsers. For this purpose, we use the state-of-the-art text-to-image generation model DALL-E [20], which automatically generates images from text prompts and has a high zero-shot performance. We obtain candidates for phrase correspondences from CCG syntactic trees and semantic representations, and we recognize them as such when the images generated by DALL-E from each phrase are similar. Our primary contribution in this study is providing a new way of solving RTE problems by using a text-to-image generation model to acquire phrasal knowledge. We improve the performance of ccg2lambda on the SICK dataset [15] compared with a previous logical approach with knowledge injection, especially in terms of recall.

2 Methodology

2.1 System Overview

We consider RTE problems consisting of premise–hypothesis pairs annotated with three relations: entailment (*yes*), contradiction (*no*), and neutral (*unknown*). Our system is based on ccg2lambda with SPSA, an RTE system in which the on-demand injections of lexical knowledge are guided by a natural deduction theorem prover [17]. First, the system parses premise and hypothesis sentences into CCG syntactic trees with the C&C parser [5] and obtains semantic representations from them. Second, the system uses Coq [2] to prove whether a premise entails a hypothesis. Coq is an interactive natural deduction theorem prover that is fully au-

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[1] https://github.com/mynlp/ccg2lambda

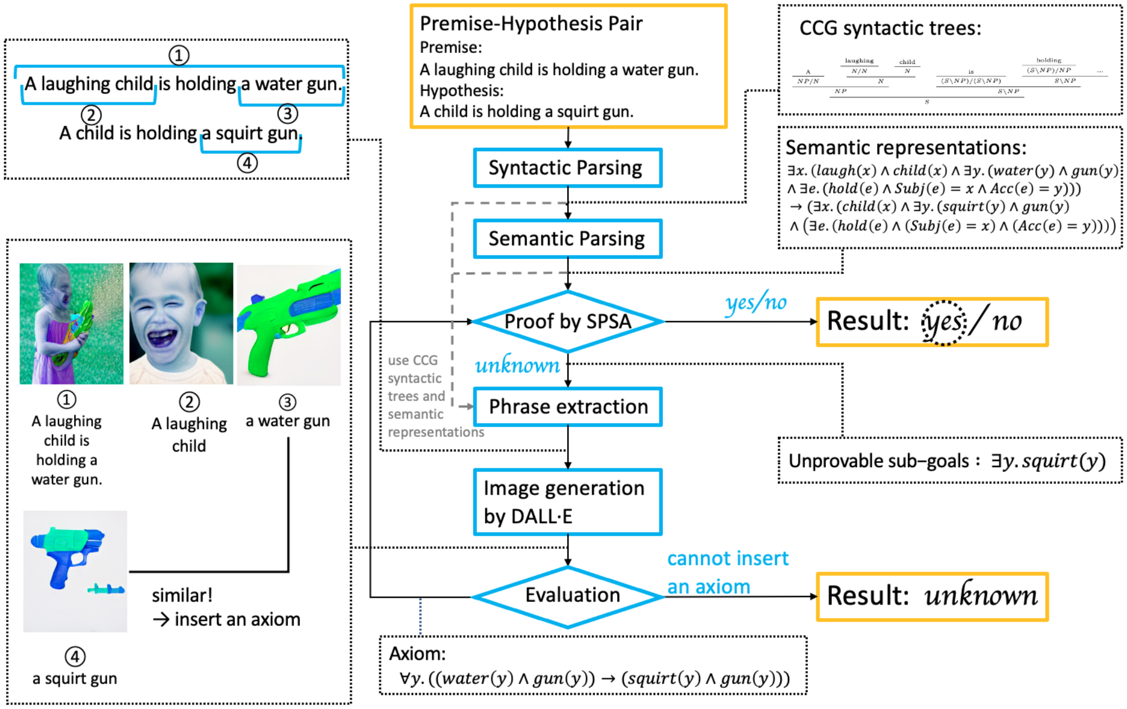


Fig. 1: Overview of the proposed method with an example. We try to prove whether a premise entails a hypothesis by SPSA (Selector of Predicates with Shared Arguments). If SPSA outputs *unknown*, we perform phrase extraction, image generation by DALL-E, and image evaluation. Depending on the result of the image evaluation, we either insert an axiom and continue the proof by SPSA or finish the proof with the result *unknown* when we do not obtain any axioms.

tomatic with several built-in theorem-proving routines called tactics. In a proof process, SPSA monitors the proof and finds unprovable sub-goals that have the same arguments with logical predicates of premises. Then, SPSA retrieves word-to-word relations from external knowledge databases such as WordNet, inserts corresponding axioms on demand, and proves the entailment relations again. Note that the original SPSA is limited to capturing word-to-word relations since it does not retrieve phrase-to-phrase relations. We enable the capture of phrase-to-phrase relations by combining a text-to-image generation model and ccg2lambda with SPSA. The proof process for our system is as follows:

1. Try to prove whether a premise entails a hypothesis by SPSA. If the result is *yes* or *no*, then finish the proof. If not, then go to 2.
2. Try to insert a phrasal axiom using DALL-E (Sections 2.2 and 2.3). If a phrasal axiom is inserted, then return to 1. If not, then finish the proof with the result *unknown*.

Steps 1 and 2 are repeated for all the unprovable sub-goals.

2.2 Phrase Extraction

We define a phrase as any part of a sentence corresponding to an NP (noun phrase), a VP (verb phrase), a PP (prepositional phrase), or an S (sentence) in CCG syntactic trees. When the result of SPSA is *unknown*, we sample one sub-goal from the unprovable sub-goals. We use CCG syntactic trees and semantic representations to extract phrases from premise–hypothesis pairs. We extract all phrases from the premise, but we extract only the minimum phrase that contains the unprovable sub-goal in the semantic representation from the hypothesis.

2.3 Image Generation and Evaluation

Using DALL-E, we generate two images from each extracted phrase. For each premise phrase, we calculate its *phrase distance* from the hypothesis phrase. We define the phrase distance between a phrase p from a premise and a phrase h from a hypothesis as

$$dis(p,h) = \frac{1}{|I_p|} \sum_{i_p \in I_p} \min_{i_h \in I_h} \{\omega_c f(i_p, i_h) + \omega_g f(gray(i_p), gray(i_h))\}, \quad (1)$$

where

- I_p and I_h are sets of images generated from p and h,
- $gray(i)$ is a grayscale image converted from the image i,
- ω_c and ω_g are parameters of the phrase distance for which $0 \leq \omega_c, \omega_g \leq 1$, and $\omega_c + \omega_g = 1$, and
- f is a function from AugNet [4] for calculating the distance between two images.

The reasoning behind this definition is that if p entails h (i.e, if h necessarily follows from p), then each image in I_p is likely to be similar to at least one image in I_h. The motivation here is to express the non-symmetrical relation between the premise phrase and the hypothesis phrase.

If the minimum distance between the premise phrase and the hypothesis phrase is shorter than a certain threshold, then we recognize the closest phrase pair as a phrase correspondence, insert the phrasal axiom, and continue the proof by SPSA. The phrasal axiom is formulated by converting the corresponding semantic representations of both phrases into a Coq script. If we do not obtain any phrase correspondences, then we do not insert any phrasal axioms and finish the proof with the result *unknown*.

3 Experiment

Experimental Setup We used the SemEval-2014 version of the SICK dataset [15]. This dataset contains problems involving lexical and logical phenomena. Thus, lexical and phrasal knowledge is needed to correctly predict the entailment labels of these problems. The SICK dataset contains problems with train/trial/test splits of 4500/500/4927 premise–hypothesis pairs and a yes/no/unknown label distribution of .29/.15/.56. We used the test set to evaluate our system. We changed the parameters ω_c and ω_g in (1) and the thresholds of the phrase distance, then compared the results.

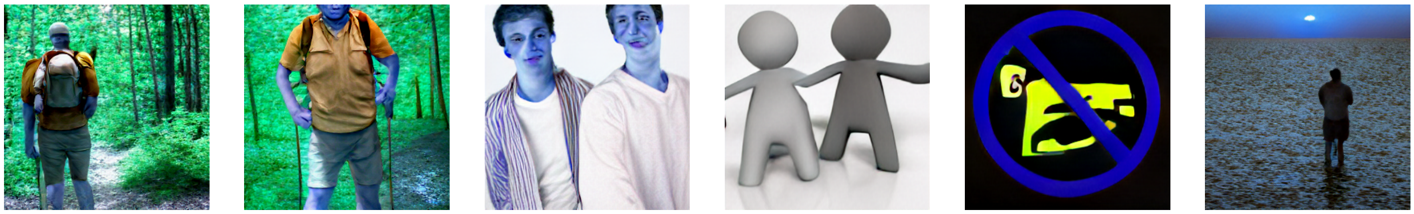
Results Table 1 shows our experimental results. The thresholds are the integer values from 15 to 20 with which we obtained the highest accuracies on 100 randomly chosen examples from the SICK dataset. We obtained higher accuracy (83.79 versus 83.13), recall (63.30 versus 62.65), and F-measure (76.11 versus 76.08) over the SPSA baseline when $\omega_c = 0.7$ and $\omega_g = 0.3$, although the precision was lower than the baseline (95.43 versus 96.65). One reason for the low precision was the over-generation of axioms, which resulted in more wrong axioms being inserted with a larger threshold.

ω_c	ω_g	Threshold	Acc.	Prec.	Rec.	F-measure
0	1	15	83.53	95.05	63.61	**76.17**
0.3	0.7	17	83.58	94.69	63.58	76.08
0.5	0.5	16	83.67	94.63	**63.68**	76.13
0.7	0.3	16	**83.79**	**95.43**	63.30	76.11
1	0	15	83.32	94.62	63.61	76.07
SPSA			83.13	96.95	62.65	76.08
Han et al. (2017)			84.29	90.24	71.08	79.52
No axioms			76.65	98.90	46.48	63.24

Table 1: RTE results on the SICK dataset. We select the threshold that maximizes the F-measure per parameter pair.

Analysis Figure 2 shows images generated by DALL-E from extracted phrases. Figures 2a and 2b show examples of our system producing positive results, where similar images were successfully generated by DALL-E from a similar concept being conveyed with different phrases. In all the examples that were proved correctly with phrasal axioms, we observed that only one phrasal axiom was inserted by our system. Figures 2c and 2d show examples of our system producing a negative result. An axiom for the phrase correspondence *Two men* $\rightarrow$ *Two people* was correct, and proper images were generated by DALL-E. However, the distance between the two images, calculated by f in (1), was long, so our system did not insert the axiom for the phrase correspondence. This shows that the phrase distance (1) alone cannot fully capture the relationship between the two images, and it even leads to a substantial number of errors. In future work, we will compare different text-to-image generation models and distance metrics to see if they can improve our method of comparing images. Another interesting direction for future work is to calculate phrase distances by using text embedding vectors in vision-and-language models.

Figures 2e and 2f show another example of our system producing a negative result. These were generated from phrases containing negation, and they do not sufficiently express the meanings of those phrases. A recent study [21] reported on the challenges involved in expressing visual denotations of negation, and how to deal with these types of phrases is an issue that remains to be solved.



(a) A man is trekking in the woods (b) The man is hiking in the woods (c) Two men (d) Two people (e) No man (f) Nobody is standing in the ocean

Fig. 2: Images generated by DALL-E from phrases. (a) and (b) are from the problem with ID 3184 (Premise: A man is trekking in the woods., Hypothesis: The man is hiking in the woods., Gold: *yes*, SPSA: *unknown*, Our system: *yes*, Phrase correspondence of the inserted axiom: *A man is trekking in the woods* $\rightarrow$ *The man is hiking in the woods*). (c)-(f) are images that led to incorrect results. (c) and (d) are from the problem with ID 9613 (Premise: Two men are seated on a camel and another camel is in the foreground., Hypothesis: Two people are seated on a camel and another camel is in the foreground., Gold: *yes*, SPSA: *unknown*, Our system: *unknown*). (e) and (f) are generated from phrases containing negation.

4 Conclusion

In this paper, we introduced a new phrase abduction mechanism for the higher-order inference system ccg2lambda that uses the state-of-the-art text-to-image generation model DALL-E. Our experimental results demonstrated that our system can obtain knowledge from long phrases. Our system improved the recall and accuracy of ccg2lambda on the SICK dataset compared with the previous system, which used the word-level abduction mechanism SPSA. In this paper, we measured phrase distances by calculating the distances between images generated by a text-to-image generation model, allowing us to use the image information for phrasal knowledge. We can also measure phrase distances by calculating the distances between embedding vectors of phrases in a vision-and-language model, but we leave this for future work.

5 Acknowledgements

We thank the two anonymous reviewers for their helpful comments and suggestions. We also thank Tomoya Kurosawa and Tomoki Sugimoto for their helpful advice on writing our paper. This work was supported by JST, PRESTO Grant Number JPMJPR21C8, Japan.

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Answers, Exhaustivity, and Presupposition of *wh*-questions in Dependent Type Semantics

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1 Introduction

In this paper, I analyze direct and embedded *who/which* questions in Dependent Type Semantics (DTS) [1, 2], which is one of the frameworks of proof-theory-based natural language semantics. This study presents a different strategy than the preceding analysis of interrogatives in DTS [15]. The previous study [15] explains the relationship between questions and answers in terms of inferences since DTS is a semantic framework based on proof-theoretic semantics. My analysis inherits this idea, but differs in the following respects:

- I do not assume lexical ambiguity in *wh*-words.
- I analyze *wh*-words itself as a lambda abstractor, and let empty operators play the role of existential quantifiers.

The second point in particular may seem eccentric, but it paves the way to a proper analysis of embedded interrogatives in DTS[1].

In the current method, various levels of answers to a question are predicted to be answers based on a single semantic representation (for short, SR) of the interrogative (Section 3.1), whereas most existing approaches account for multiple levels of answers by assuming the ambiguity of interrogatives. In addition, the analysis will also be extended to embedded interrogatives (Section 3.2), which were not yet addressed in [15]. I will attempt to solve several puzzles regarding presupposition and exhaustivity of *wh*-complements, satisfying general requirements in the semantics of clause-embedding predicates.

Section 2 presents the issues that this analysis seeks to resolve. Then, in Section 3, I sketch the analysis and how it solves the problems in Section 2.

2 Empirical facts taken into account

2.1 Possible answers

There are at least three levels of answers to a question: mention-some (MS), weak exhaustivity (WE), and strong exhaustivity (SE). As an example, consider the following question:

(1) Who danced? (**Situation**: John and Susan danced, and Mary didn't dance.)

The answers to this question, corresponding to each level, are as follows.

(2) a. John danced. (Mention-some answer)
b. John and Susan danced. (Weakly exhaustive answer)
c. John and Susan danced, and Mary didn't dance. (Strongly exhaustive answer)

Traditional methods [7, 5] and subsequent analyses based on them attempt to capture these answer levels by assuming the ambiguity of interrogatives. In the proposed analysis, which treats declaratives and interrogatives in a unified way and formulates answerhood by the general relation of entailment, the variety of answers is captured based on a single SR of each interrogative.

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†I sincerely thank Takashi Sakuragawa, Matthew de Brecht, Nayuta Miki, Mizuki Yamamoto, and two anonymous reviewers for their insightful discussions and comments.

[1]This treatment also gives the possibility of realizing the propositional-answer-oriented approach (e.g. [6, 7, 5, 3]) and the constituent-answer-oriented approach (e.g. [14, 8, 4]), which are often thought to be essentially different, in a single theory.

2.2 Exhaustivity and presupposition in embedded contexts

2.2.1 Exhaustivity

Question-embedding sentences are ambiguous about exhaustivity. In principle, each proposition in (4) is possible as a paraphrase of (3) (let V be some responsive predicate)[2].

(3) Annie V who danced. (**Situation**: John and Susan danced, and Mary didn't dance.)

(4) a. There is a $p \in \{\text{John danced}, \text{Susan danced}\}$ s.t. Annie V p. (Mention-some reading)
b. For all $p \in \{\text{John danced}, \text{Susan danced}\}$, Annie V p. (Weakly exhaustive reading)
c. For all $p \in \{\text{John danced}, \text{Susan danced}\}$, Annie V p and Annie V Mary didn't dance. (Strongly exhaustive reading)

As a related example, the following inference is valid only under the strongly exhaustive reading of *John knows who danced.*

(5) a. John knows who danced. (Strongly exhaustive reading)
b. Mary didn't dance.
c. $\therefore$ John knows Mary didn't dance.

A natural application of the DTS-based analysis of interrogatives [15] to that of factive predicates [12] yields the following analyses.

(6) a. John knows who danced. (Mention-some reading)
b. $\mathbf{know}(j)\,((x : \mathbf{e}) \oplus \mathbf{d}(x))\,(@)$

(7) a. John knows who danced. (Strongly exhaustive reading)
b. $\mathbf{know}(j)\,((x : \mathbf{e}) \to \mathbf{d}(x) \uplus \neg\mathbf{d}(x))\,(@)$

The SR in (7-b) does not capture the inference pattern as in (5). In addition, the following sentences are predicted to be semantically equivalent.

(8) a. John knows who danced. (Strongly exhaustive reading)
b. John knows that each person either danced or did not dance.

Also, with regard to the mention-some reading (6), the following inferences are not predicted unless some additional axiom is added.

(9) a. John knows who danced. (Mention-some reading)
b. $\therefore$ John knows of at least one person that he or she danced.

I will give a different strategy, which accounts for these inferences (sketched in Section 3.2).

2.2.2 Presupposition

Factive predicates that take *wh*-complement trigger the existential presupposition.

(10) a. John knows who danced. *presupposes* Someone danced.
b. John knows which student danced. *presupposes* Some student danced.

It is also widely known that factive predicates trigger the factive presupposition.

(11) John knows that Sue smokes. *presupposes* Sue smokes.

[2] In addition to the interpretations listed in (4), the intermediate exhaustive readings are also said to be possible [9]. This reading is not considered in this study. I thank the two anonymous reviewers for pointing this out.

2.2.3 Uniformity of the responsive predicates' meaning

So far, I have observed exhaustivity and presupposition in the embedding context. I aim to account for them under a uniform meaning of each responsive predicate. That is, it is not assumed that responsive predicates have different meanings when taking a declarative and when taking an interrogative. The following examples support this treatment:

(12) Alice knows/realized/reported that Ann left and Bill ~~knows/realized/reported~~ which other girls left.

[13, p. 2]

(13) Alice knows who danced and that John hosted the dance party.

These suggest that a single predicate can simultaneously take a declarative complement and an interrogative one.

In this paper, I introduce three unpronounced operators to derive each interpretation in (4). The issue of ambiguity regarding exhaustivity is reduced to the choice of these operators. Also, I show that an existing analysis of factive predicates [12], motivated by the factive presupposition as in (11), can be applied to the existential presupposition as in (10).

3 Proposal

3.1 Direct questions

I analyze *who/which* questions as Σ-types[3]. In the analysis here, *wh*-words create an abstract, which is fed to the unpronounced operator $\varnothing_{\mathsf{Q}}$ I define in (14)[4]. $\varnothing_{\mathsf{Q}}$ is assumed to appear at the beginning of *wh*-interrogatives.

(14) $\varnothing_{\mathsf{Q}} := S_{wq}/(S_{wqa}/NP) : \lambda p.(x : \mathbf{e}) \times p(x)$

The followings are examples of the analysis.

(15) a. Who danced?
b. $(x : \mathbf{e}) \times \mathbf{d}(x)$

(16) a. Which student danced?
b. $(x : \mathbf{e}) \times (\mathbf{s}(x) \times \mathbf{d}(x))$

The mapping from (15-a) to (15-b) is obtained by the following CCG derivation tree:

(17)
$$\dfrac{\begin{array}{c}\varnothing_{\mathsf{Q}}\\ S_{wq}/(S_{wqa}/NP) :\\ \lambda p.(x : \mathbf{e}) \times p(x)\end{array} \quad \dfrac{\begin{array}{c}\text{Who}\\ (S_{wqa}/NP)/(S\backslash NP) : \lambda p.\lambda x.p(x)\end{array} \quad \begin{array}{c}\text{danced}\\ S\backslash NP : \lambda x.\mathbf{d}(x)\end{array}}{S_{wqa}/NP : \lambda x.\mathbf{d}(x)}>}{S : (x : \mathbf{e}) \times \mathbf{d}(x)}>$$

SRs of embedded interrogatives are derived by operators different from $\varnothing_{\mathsf{Q}}$ (see next section). To sum up, the strategy of this study is that a *wh*-interrogative, by itself, has only one SR (i.e., an abstract), and various SRs are derived from this[5].

[3]A term of the form $\begin{bmatrix} x : A \\ B(x) \end{bmatrix}$ is called a Σ-type. To save space, this is often written as $(x : A) \times B(x)$. For a more formal exposition of DTS, see [1, 2, 11].

[4]This study adopts Combinatory Categorial Grammar (CCG; [10]) as a syntactic component and therefore defines lexical entries in the following form: PF := CCG category : SR

[5]The part of the derivation of (17) that does not involve $\varnothing_{\mathsf{Q}}$ embodies the idea of the so-called categorial approach: an interrogative is itself an incomplete object, and when combined with a characteristic short answer it becomes a sentence.

In the preceding analysis [15], answerhood is defined via entailment. Adding (19-a) and (19-c) to this original definition, we define answerhood as follows:

(19) Let S_Q, and S_A be types, and $\mathcal{K}$ be a global context. S_A is an answer to S_Q iff (19-a) and either of (19-b) and (19-c) hold.

a. $\mathcal{K}, a : S_A \nvdash \bot\ \mathit{true}$

b. $\mathcal{K}, a : S_A \vdash S_Q\ \mathit{true}$

c. $\mathcal{K}, a : S_A \vdash \neg S_Q\ \mathit{true}$

Under (19), the answers mentioned in Section 2.1 are predicted to be answers.

Furthermore, the proposed analysis allows us to capture the impossibility of self-denial of the existence of a positive answer (except in the case of a rhetorical question). For example, the following utterance would sound contradictory.

(20) #Nobody danced. Who danced?

This mini-discourse has the following SR, which leads to contradiction, as expected.

$$(21)\quad \begin{bmatrix} (x : \mathbf{e}) \to \neg\mathbf{d}(x) \\ (x : \mathbf{e}) \times \mathbf{d}(x) \end{bmatrix}$$

3.2 Embedded questions

Here I define three unpronounced operators whose SRs map a direct question into an embedded question. It is assumed that one of these will appear at the beginning of interrogative complements. The ambiguity about exhaustivity is due to the choice of these operators.

(22) $\varnothing_{\mathsf{MS}} := S\backslash(S/\bar{S})/(S_{wqa}/NP) : \lambda F.\lambda V.(x : \mathbf{e}) \times V(F(x))$

$$(23)\quad \varnothing_{\mathsf{WE}} := S\backslash(S/\bar{S})/(S_{wqa}/NP) : \lambda F.\lambda V. \begin{bmatrix} (x : \mathbf{e}) \to F(x) \to V(F(x)) \\ V\left((y : \mathbf{e}) \times F(y)\right) \end{bmatrix}$$

$$(24)\quad \varnothing_{\mathsf{SE}} := S\backslash(S/\bar{S})/(S_{wqa}/NP) : \lambda F.\lambda V. \begin{bmatrix} (x : \mathbf{e}) \to \begin{bmatrix} F(x) \to V(F(x)) \\ \neg F(x) \to V(\neg F(x)) \end{bmatrix} \\ V\left((y : \mathbf{e}) \times F(y)\right) \end{bmatrix}$$

Then, the SR of the sentence (25) can be obtained in three ways, depending on the choice of the operators. Each SR is shown in (26). The lexical item of *know* is that given in [12, p. 404] concerning declarative complements.

(25) John knows who danced.

(26) a. Mention-some reading:

$$\text{John knows } \varnothing_{\mathsf{MS}} \text{ who danced} \mapsto \begin{bmatrix} x : \mathbf{e} \\ \mathbf{know}(john)\,(\mathbf{d}(x))\,(@_1) \end{bmatrix}$$

---

(18) a. Who danced?

b. John.

c.
$$\dfrac{\dfrac{\overset{\text{Who}}{(S_{wqa}/NP)/(S\backslash NP) : \lambda p.\lambda x.p(x)} \quad \overset{\text{danced}}{S\backslash NP : \lambda x.\mathbf{d}(x)}}{S_{wqa}/NP : \lambda x.\mathbf{d}(x)}{>} \quad \overset{\text{John}}{NP : j}}{S_{wqa} : \mathbf{d}(j)}{>}$$

In words, the proposed analysis can probably be converted to a categorial theory by detaching null operators from the lexicon. In this sense, the current analysis is potentially a hybrid theory. Further discussion on this point is warranted, but I will leave that for another occasion.

b. Weakly exhaustive reading:

$$\text{John knows } \varnothing_{\mathsf{WE}} \text{ who danced} \mapsto \begin{bmatrix} (x : \mathbf{e}) \to \mathbf{d}(x) \to \mathbf{know}(john)(\mathbf{d}(x))(@_2) \\ \mathbf{know}(john)\left(\begin{bmatrix} y : \mathbf{e} \\ \mathbf{d}(y) \end{bmatrix}\right)(@_1) \end{bmatrix}$$

c. Strongly exhaustive reading:

$$\text{John knows } \varnothing_{\mathsf{SE}} \text{ who danced} \mapsto \begin{bmatrix} (x : \mathbf{e}) \to \begin{bmatrix} \mathbf{d}(x) \to \mathbf{know}(john)(\mathbf{d}(x))(@_2) \\ \neg\mathbf{d}(x) \to \mathbf{know}(john)(\neg\mathbf{d}(x))(@_3) \end{bmatrix} \\ \mathbf{know}(john)\left(\begin{bmatrix} y : \mathbf{e} \\ \mathbf{d}(y) \end{bmatrix}\right)(@_1) \end{bmatrix}$$

These SRs lead us to predict that the inference (5) is only valid under the SE reading. With respect to the existential presupposition, it is predicted that for the SR of *John knows who danced* to be well-formed, the SR of *Someone danced* must be true. These are desirable results.

4 Limitations and future work

It is necessary to extend the analysis to more types of interrogatives. Besides, it is not evident whether the proposed analysis can predict which predicates will select which exhaustivity. In addition, comparisons with other frameworks, such as inquisitive semantics [3], are also required. These will be discussed on another occasion. As mentioned in several footnotes, this theory can also embody a question-as-function view (e.g. [14, 8, 4]) that is adept at dealing with non-sentential answers. This feature is desirable, given that the strengths of theories with sentential answers in mind and theories with non-sentential answers in mind are complementary and that a question-answering task needs to be able to handle both types of answers. This perspective has not been discussed in this paper and is needed in the future.

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A PROOF-THEORETIC ANALYSIS OF MEANING OF A FORMULA IN A COMBINATION OF INTUITIONISTIC AND CLASSICAL PROPOSITIONAL LOGIC

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ABSTRACT

This paper studies a proof-theoretic analysis of the meaning of a formula in a combination of intuitionistic and classical propositional logic, called $\mathbf{C}+\mathbf{J}$.[1] This logic was provided in [1, 2], and the analysis uses the sequent calculus $\mathsf{G}(\mathbf{C}+\mathbf{J})$, which was proposed in [3]. The analysis given in this paper is based on the one provided by Restall [4], but by employing the method proposed by Takano [5], a more refined analysis is proposed. This paper has four sections. Section 1 reviews Restall's analysis and states two points of improvement. Section 2 introduces the sequent calculus $\mathsf{G}(\mathbf{C}+\mathbf{J})$. Section 3 displays the proof-theoretic analysis of the meaning of a formula in $\mathbf{C}+\mathbf{J}$, by making use of Takano's method. Section 4 introduces two positions called unilateralism and bilateralism and describes an outline of a unilateral analysis for $\mathbf{C}+\mathbf{J}$.

1. RESTALL'S ANALYSIS

The main idea of Restall [4]'s analysis is to interpret inference rules in a sequent calculus as *normative constraints* on *assertion* and *denial*, and obtaining a model from those inference rules. Thus, his analysis is different from proof-theoretic semantics in that a syntactical object such as an argument or a deduction is not directly used to explain the meaning of a formula. Since Restall's analysis technically corresponds a canonical model argument, it provides a view of a proof of semantic completeness from linguistic acts, such as assertion and denial. Restall applied his analysis to classical logic, intuitionistic logic, and modal logic $\mathbf{S5}$. Only the case of classical logic, where the sequent calculus $\mathbf{LK}$ is used, is described here. Since the arguments about conjunction and disjunction are similar, only the former is mentioned here.

The central notion of his analysis is the notion of a *position*, defined as below.

Definition 1. [4, Definition 1] A pair $(\Gamma : \Delta)$ of sets of formulas is a *position* if $\Gamma \Rightarrow \Delta$ is not derivable in $\mathbf{LK}$.

In the rest of this paper, $(\Gamma \cup \{A\} : \Delta \cup \{B\})$ is abbreviated as $(\Gamma, A : \Delta, B)$, for any sets Γ, Δ of formulas and formulas A, B. For example, $(p : p \wedge q)$ is a position, while $(p : p \vee q)$ is not. Restall regards the antecedents and the succedents of a sequent as *asserted* and *denied* formulas respectively. A position is an expression of a consistent situation with respect to assertion and denial. The example described above represents the fact that it is consistent to assert p and deny $p \wedge q$, while it is inconsistent to assert p and deny $p \vee q$. Accordingly, the derivability of $\Gamma \Rightarrow \Delta$ implies that it is inconsistent to assert all of the formulas in Γ and deny all of the formulas in Δ. In Restall's analysis, inference rules are interpreted in light of the notion of a position. Consider the following rule:

$$\frac{A, \Gamma \Rightarrow \Delta}{A \wedge B, \Gamma \Rightarrow \Delta.}$$

[1] Katsuhiko Sano, the supervisor of the author, gave many helpful comments. This research is partially supported by Grant-in-Aid for JSPS Fellows Grant Number JP22J20341.

The following is obtained by the contrapositive of this rule: if $(A \wedge B, \Gamma : \Delta)$ is a position, then $(A, \Gamma : \Delta)$ is also a position. Since a position expresses a consistent situation with respect to assertion and denial, this rule functions as a normative constraint on a linguistic act.

Definition 2. [4, Definition 4] A pair $(\Gamma : \Delta)$ of sets of formulas is a *limit position* if it satisfies the following:

- For any finite sets $\Gamma' \subseteq \Gamma$, $\Delta' \subseteq \Delta$ of formulas, the pair $(\Gamma' : \Delta')$ is a position.
- The union of Γ and Δ contains all formulas in classical logic.

Fact 3. [4, Fact 4] For any position $(\Gamma : \Delta)$, there is a limit position $(\Gamma^* : \Delta^*)$ such that $\Gamma \subseteq \Gamma^*$ and $\Delta \subseteq \Delta^*$.

Fact 4. [4, Fact 5] For any limit position $(\Gamma : \Delta)$, all of the following hold:

(1) $A \wedge B \in \Gamma$ iff both $A \in \Gamma$ and $B \in \Gamma$ hold,
(2) $A \wedge B \in \Delta$ iff either $A \in \Delta$ or $B \in \Delta$ hold,
(3) $\neg A \in \Gamma$ iff $A \in \Delta$,
(4) $\neg A \in \Delta$ iff $A \in \Gamma$.

Fact 3 ensures that any position can be extended to some limit position, and Fact 4 establishes that a formula in Γ and Δ can be regarded as true and false, respectively. Although the meaning of a formula is explained by a model, since it is not introduced as given but obtained from the admissibility of inference rules in **LK**, Restall's analysis should be regarded as proof-theoretic.

However, two points of improvement exist in Restall's analysis. Firstly, although Restall's analysis obtains the satisfaction relation for a complex formula from the admissibility of corresponding inference rule, an analysis which establishes the equivalence between them is better, since it describes the tighter relation between them. Secondly, if an analysis without assuming the admissibility of the rule (Cut) is proposed, such an analysis will be better than Restall's in that it uses less assumptions, since Restall's analysis depends on (Cut), formulated as follows:

$$\frac{\Gamma \Rightarrow \Delta, A \quad A, \Gamma \Rightarrow \Delta}{\Gamma \Rightarrow \Delta}\ (Cut).$$

The analysis without depending on (Cut) will be presented in Section 3. In addition to the analysis assuming less assumptions, it provides a semantic condition corresponding to the admissibility of (Cut), as other rules for connectives. In the rest of this paper, if the side condition $A \in \mathsf{Sub}(\Gamma \cup \Delta)$ is imposed, this restricted rule will be called "analytic cut rule", denoted by (Cut^a).

2. A Combination $\mathbf{C} + \mathbf{J}$

A syntax of the combination $\mathbf{C} + \mathbf{J}$ has a countably infinite set of propositional variables and the following logical connectives: falsum $\bot$, conjunction $\wedge$, disjunction $\vee$, intuitionistic implication $\to_{\mathtt{i}}$, and classical negation $\neg_{\mathtt{c}}$. Intuitionistic negation $\neg_{\mathtt{i}}$ and classical implication $\to_{\mathtt{c}}$ are defined as follows: $\neg_{\mathtt{i}} A := A \to_{\mathtt{i}} \bot$, $A \to_{\mathtt{c}} B := \neg_{\mathtt{c}} A \vee B$. A logical connective other than implications and negations is regarded as common to intuitionistic and classical logic. The semantics of $\mathbf{C} + \mathbf{J}$ is provided in [1, 2] and is obtained by adding to ordinary intuitionistic Kripke semantics (cf. [6]) the satisfaction relation for "$\neg_{\mathtt{c}}$", described as follows: $w \models_M \neg_{\mathtt{c}} A$ iff $w \not\models_M A$, where M is an intuitionistic Kripke model, and w is a possible world in M.

As a proof theory to analyze the meaning of a formula in $\mathbf{C} + \mathbf{J}$, this paper employs the sequent calculus $\mathsf{G}(\mathbf{C} + \mathbf{J})$, proposed in [3]. This calculus is obtained by adding to the propositional fragment of the classical sequent calculus $\mathbf{LK}$ the following rules for "$\to_{\mathtt{i}}$":

$$\frac{A, C_1 \to_{\mathtt{i}} D_1, \ldots, C_m \to_{\mathtt{i}} D_m, p_1, \ldots, p_n \Rightarrow B}{C_1 \to_{\mathtt{i}} D_1, \ldots, C_m \to_{\mathtt{i}} D_m, p_1, \ldots, p_n \Rightarrow A \to_{\mathtt{i}} B}\ (\Rightarrow \to_{\mathtt{i}}) \quad \frac{\Gamma \Rightarrow \Delta, A \quad B, \Gamma \Rightarrow \Delta}{A \to_{\mathtt{i}} B, \Gamma \Rightarrow \Delta}\ (\to_{\mathtt{i}} \Rightarrow).$$

Although a form of an antecedent is restricted in the right rule for "$\to_{\mathtt{i}}$", no restriction is needed for the left rule. The sequent calculus $\mathsf{G}(\mathbf{C}+\mathbf{J})$ is *cut-free* and satisfies the subformula property.

3. Improvement of Restall's Analysis by Takano's Method

Since Takano [5]'s method obtains a model from the admissibility of inference rules, its fundamental idea is similar to Restall's idea, though the interpretation based on assertion and denial was not employed in [5]. As in Section 1, the argument about disjunction is omitted.

Stipulation 5. [5, Stipulation 1] The sequent calculus is the calculus having $A \Rightarrow A$ as an axiom for any A and having weakening and contraction rules.

By Stipulation 5, a sequent calculus containing only some rules in $\mathsf{G}(\mathbf{C}+\mathbf{J})$ can be discussed. It is noted that the existence of (Cut) or $(Cut)^a$ is not assumed. In the following, let $\mathbf{GL}$ be a sequent calculus.

Definition 6. Let A be any formula. We define $\mathsf{Sub}(A)$ as the set of all subformulas of A. Let Γ be a finite set of formulas. Then, we define $\mathsf{Sub}(\Gamma)$ as the set of all subformulas of some formulas in Γ. A set Γ of formulas is *subformula-closed (sf-closed)* if $\mathsf{Sub}(\Gamma) \subseteq \Gamma$ and $\bot \in \Gamma$.

In the following, a sf-closed finite set Ξ of formulas is considered, while it is not considered in [5]. However, such a set is considered in [7, 8, 9], and a finite model will be obtained by considering it.

Definition 7. [7, Definition 2 (1)] Let Ξ be a sf-closed finite set of formulas and $\Gamma \cup \Delta \subseteq \Xi$. A sequent $\Gamma \Rightarrow \Delta$ is Ξ*-derivable* in $\mathbf{GL}$ if it has a derivation in $\mathbf{GL}$ consisting solely of formulas in Ξ.

Instead of the notion of a position, the notion of a Ξ*-analytically saturated pair* is introduced.

Definition 8. Let Ξ be a sf-closed finite set of formulas. A pair $(\Gamma : \Delta)$ of finite sets of formulas is Ξ*-analytically saturated* in a sequent calculus $\mathbf{GL}$ if it satisfies all of the following:

(1) $\Gamma \Rightarrow \Delta$ is not Ξ-derivable in $\mathbf{GL}$.
(2) For any formula $A \in \Xi$,
  - $A \in \Gamma$ if $A, \Gamma \Rightarrow \Delta$ is not Ξ-derivable in $\mathbf{GL}$,
  - $A \in \Delta$ if $\Gamma \Rightarrow \Delta, A$ is not Ξ-derivable in $\mathbf{GL}$,

(3) $\mathsf{Sub}(\Gamma \cup \Delta) \subseteq \Xi$.

Lemma 9. Let Ξ be a sf-closed finite set of formulas. Consider a set $\Gamma \cup \Delta$ of formulas and suppose that $\Gamma \Rightarrow \Delta$ is not derivable in $\mathbf{GL}$ and $\mathsf{Sub}(\Gamma \cup \Delta) \subseteq \Xi$. Then, there exists a Ξ-analytically saturated pair $(\Gamma^* : \Delta^*)$ such that $\Gamma \subseteq \Gamma^*$, $\Delta \subseteq \Delta^*$, and $\Gamma^* \cup \Delta^* \subseteq \Xi$.

Lemma 9 ensures that any underivable pair of sets of formulas can be extended to some Ξ-analytically saturated pair. In the following, the set of all Ξ-analytically saturated pairs is denoted by W^{Ξ}. From (3) of Definition 8, W^{Ξ} is finite, since Ξ is finite.

Definition 10. For any $(\Gamma : \Delta), (\Pi : \Sigma) \in W^{\Xi}$, $(\Gamma : \Delta) R^{\Xi} (\Pi : \Sigma)$ if the following hold:

- For any propositional variable $p \in \Xi$, if $p \in \Gamma$, then $p \in \Pi$,
- For any formulas $A \to_{\mathtt{i}} B \in \Xi$, if $A \to_{\mathtt{i}} B \in \Gamma$, then $A \to_{\mathtt{i}} B \in \Pi$.

Definition 11. For any propositional variable $p \in \Xi$ and any $(\Gamma : \Delta) \in W^{\Xi}$, a valuation V^{Ξ} is defined as follows:

$$(\Gamma : \Delta) \in V^{\Xi}(p) \quad \text{iff} \quad p \in \Gamma.$$

The obtained tuple $\langle W^{\Xi}, R^{\Xi}, V^{\Xi} \rangle$ is a Kripke model for $\mathbf{C}+\mathbf{J}$, provided in [1, 2].

Definition 12. An inference rule is Ξ*-admissible* in $\mathbf{GL}$ if whenever all of the upper sequents are Ξ-derivable in $\mathbf{GL}$, then the lower sequent is also Ξ-derivable in $\mathbf{GL}$.

Theorem 1. Define the following conditions for A, B and $(\Gamma : \Delta) \in W^{\Xi}$:

$(\neg_{\mathtt{c}}^{+})$ $\neg_{\mathtt{c}} A \in \Gamma$ implies $A \in \Delta$,
$(\neg_{\mathtt{c}}^{-})$ $\neg_{\mathtt{c}} A \in \Delta$ implies $A \in \Gamma$,
$(\wedge^{+})$ $A \wedge B \in \Gamma$ implies $A \in \Gamma$ and $B \in \Gamma$,
$(\wedge^{-})$ $A \wedge B \in \Delta$ implies $A \in \Delta$ or $B \in \Delta$,
$(\rightarrow_{\mathtt{i}}^{+})$ $A \rightarrow_{\mathtt{i}} B \in \Gamma$ implies for any $(\Pi : \Sigma) \in W^{\Xi}$ s.t. $(\Gamma : \Delta) R^{\Xi} (\Pi : \Sigma)$, $A \in \Sigma$ or $B \in \Pi$,
$(\rightarrow_{\mathtt{i}}^{-})$ $A \rightarrow_{\mathtt{i}} B \in \Delta$ implies for some $(\Pi : \Sigma) \in W^{\Xi}$ s.t. $(\Gamma : \Delta) R^{\Xi} (\Pi : \Sigma)$, $A \in \Pi$ and $B \in \Sigma$,
$(\bot)$ $\bot \notin \Gamma$,
(Max^{a}) $A \in \mathsf{Sub}(\Gamma \cup \Delta)$ implies $A \in \Gamma$ or $A \in \Delta$,
(Max) $A \in \Gamma$ or $A \in \Delta$.

Then, for any sf-closed finite set Ξ of formulas, all of the following hold:

(1) The left rule for "$\neg_{\mathtt{c}}$" is Ξ-admissible in **GL** for any contexts iff $(\neg_{\mathtt{c}}^{+})$ holds for any $(\Gamma : \Delta) \in W^{\Xi}$,
(2) The right rule for "$\neg_{\mathtt{c}}$" is Ξ-admissible in **GL** for any contexts iff $(\neg_{\mathtt{c}}^{-})$ holds for any $(\Gamma : \Delta) \in W^{\Xi}$,
(3) The left rule for "$\wedge$" is Ξ-admissible in **GL** for any contexts iff $(\wedge^{+})$ holds for any $(\Gamma : \Delta) \in W^{\Xi}$,
(4) The right rule for "$\wedge$" is Ξ-admissible in **GL** for any contexts iff $(\wedge^{-})$ holds for any $(\Gamma : \Delta) \in W^{\Xi}$,
(5) The left rule for "$\rightarrow_{\mathtt{i}}$" is Ξ-admissible in **GL** for any contexts iff $(\rightarrow_{\mathtt{i}}^{+})$ holds for any $(\Gamma : \Delta) \in W^{\Xi}$,
(6) The right rule for "$\rightarrow_{\mathtt{i}}$" is Ξ-admissible in **GL** for any contexts iff $(\rightarrow_{\mathtt{i}}^{-})$ holds for any $(\Gamma : \Delta) \in W^{\Xi}$,
(7) The rule for "$\bot$" is Ξ-admissible in **GL** iff $(\bot)$ holds for any $(\Gamma : \Delta) \in W^{\Xi}$,
(8) The rule (Cut^{a}) is Ξ-admissible in **GL** for any contexts iff (Max^{a}) holds for any $(\Gamma : \Delta) \in W^{\Xi}$,
(9) The rule (Cut) is Ξ-admissible in **GL** for any contexts iff (Max) holds for any $(\Gamma : \Delta) \in W^{\Xi}$.

Theorem 2. Let Ξ be a sf-closed finite set of formulas. Suppose $(\neg_{\mathtt{c}}^{+})$, $(\neg_{\mathtt{c}}^{-})$, $(\wedge^{+})$, $(\wedge^{-})$, $(\rightarrow_{\mathtt{i}}^{+})$, $(\rightarrow_{\mathtt{i}}^{-})$, and $(\bot)$ are satisfied for W^{Ξ}. Then, for any $(\Gamma : \Delta) \in W^{\Xi}$ and any formula $C \in \Xi$ which has no occurrence of "$\vee$", the following hold:

$$C \in \Gamma \text{ implies } (\Gamma : \Delta) \models C \text{ and } C \in \Delta \text{ implies } (\Gamma : \Delta) \not\models C.$$

The analysis in this section overcomes the two points of improvement of Restall's analysis. Firstly, in Theorem 1, the equivalence between the admissibility of an inference rule and the corresponding satisfaction relation is shown. Secondly, this analysis does not depend on (Cut). Although the absence of (Cut) restricts the obtained satisfaction relations to one direction, as is seen in Theorem 1, this is sufficient to show Theorem 2. In addition, semantic conditions (Max^{a}) and (Max) for the admissibility of (Cut^{a}) and (Cut) are provided.

4. Unilateral Approach

This section explains briefly how the meaning of a formula in $\mathbf{C} + \mathbf{J}$ can be analyzed based on unilateralism. Unilateralism is a position considering only one type of linguistic act is (should be regarded as) primitive when the meaning of a formula is considered, while bilateralism considers two types are (should be regarded as) primitive. Bilateralism has been chosen so far, since both assertion and denial are used to interpret an inference rule and the derivability of a sequent. The most direct unilateral way of analyzing the meaning of a formula in $\mathbf{C} + \mathbf{J}$, employing the method in Section 3, is to regard the antecedents of an underivable pair $(\Gamma : \Delta)$ as formulas which are asserted and the succedents of it as those which are not asserted.

However, since a problem of this interpretation was already pointed out in [10], this section overviews a different way of providing unilateral analysis, which is realized by constructing the calculus for $\mathbf{C} + \mathbf{J}$ where only the antecedents of a sequent are manipulated. In the following, a set $\neg_{\mathtt{c}}\Delta$ of formulas is defined for any Δ as follows: $\neg_{\mathtt{c}}\Delta = \{\neg_{\mathtt{c}}C \mid C \in \Delta\}$.

Lemma 13. Let $\mathbf{GL}^{\neg_{\mathtt{c}}}$ be a sequent calculus obtained by adding the left and the right rules for "$\neg_{\mathtt{c}}$". For any set $\Gamma \cup \Delta$ of formulas, the following equivalence hold:

$$\Gamma \Rightarrow \Delta \text{ is derivable in } \mathbf{GL}^{\neg_{\mathtt{c}}} \text{ iff } \Gamma, \neg_{\mathtt{c}}\Delta \Rightarrow \text{ is derivable in } \mathbf{GL}^{\neg_{\mathtt{c}}}.$$

By making use of this lemma, an inference rule in $\mathsf{G}(\mathbf{C} + \mathbf{J})$ can be transformed into a different rule, where only antecedents of sequents are manipulated and no formula occurs in succedents. For example, the left rule for "$\rightarrow_{\mathtt{i}}$" in $\mathsf{G}(\mathbf{C} + \mathbf{J})$ is transformed as follows:

$$\frac{\Gamma \Rightarrow \Delta, A \quad B, \Gamma \Rightarrow \Delta}{A \rightarrow_{\mathtt{i}} B, \Gamma \Rightarrow \Delta} \quad \rightsquigarrow \quad \frac{\neg_{\mathtt{c}}A, \Gamma, \neg_{\mathtt{c}}\Delta \Rightarrow \quad B, \Gamma\neg_{\mathtt{c}}\Delta \Rightarrow}{A \rightarrow_{\mathtt{i}} B, \Gamma, \neg_{\mathtt{c}}\Delta \Rightarrow} \quad .$$

To transform all the rules in $\mathsf{G}(\mathbf{C} + \mathbf{J})$ in this way provides the calculus, where only the antecedents of a sequent is manipulated. The derivability of $\Gamma \Rightarrow$ in the calculus is interpreted as follows: it is inconsistent to assert all the formulas in Γ. This interpretation does not use the notion of denial. By employing this calculus, a unilateral analysis is realized by arranging the method in Section 3. It is also possible to arrange Restall's analysis in a unilateral manner.

It should be noted that this way of realizing unilateral analysis depends on the existence of the left and the right rules for classical negation. If classical negation were replaced with intuitionistic one, the transformation described above would be impossible, since a lemma corresponding to Lemma 13 would no longer hold. Thus, although this unilateral analysis is possible for $\mathbf{C} + \mathbf{J}$, it does not follow that the same unilateral analysis is possible for another combination, since some combination might lack the left and the right rules for classical negation.

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Logic Operators and Quantifiers in Type-Theory of Algorithms

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Abstract. In this paper introduce an extension of Moschovakis Type-Theory of Algorithms and its reduction calculus, by adding quantifiers to the logic operators. There are two kinds of terms of formulae, for designating pure and state-dependent propositions and predications. The logic operators include conjunction, disjunction, and negation. I extend the formal language by pure and state-dependent quantifiers, for enhancing the standard quantifiers of predicate logic. I provide extended reduction calculus of the Type-Theory of Acyclic Algorithms, for reductions of terms to their canonical forms.

1 Introduction to Type-Theory of Acyclic Recursion

The set $\mathsf{Types}_{\mathrm{L}^{\lambda}_{\mathrm{ar}}}$ is defined recursively, in Backus-Naur Form:

$$\tau ::= \mathsf{e} \mid \mathsf{t} \mid \mathsf{s} \mid (\tau \to \tau) \tag{Types}$$

We shall use the following abbreviations:

$$\widetilde{\sigma} \equiv (\mathsf{s} \to \sigma), \quad \text{state-dependent objects of type } \sigma \tag{1a}$$

$$\widetilde{\mathsf{e}} \equiv (\mathsf{s} \to \mathsf{e}), \quad \text{state-dependent entities} \tag{1b}$$

$$\widetilde{\mathsf{t}} \equiv (\mathsf{s} \to \mathsf{t}) \quad \text{state-dependent truth values} \tag{1c}$$

$$\begin{aligned}(\overrightarrow{\tau} \to \sigma) &\equiv (\tau_1 \to \cdots \to (\tau_n \to \sigma)) \in \mathsf{Types} (n \geq 1)\\ &\text{currying coding, for } \sigma, \tau_i \in \mathsf{Types}, \ \ i = 1, \ldots, n\end{aligned} \tag{1d}$$

Typed Vocabulary of $\mathrm{L}^{\lambda}_{\mathrm{ar}}$*:* For every $\tau \in \mathsf{Types}$, denumerable sets of typed *constants*, $K_\tau = \mathsf{Consts}_\tau = \{\mathsf{c}^\tau_0, \ldots, \mathsf{c}^\tau_k, \ldots\}$ and two kinds of infinite, denumerable sets of typed variables, *pure variables*, $\mathsf{PureVars}_\tau = \mathsf{PureV}_\tau = \{\mathsf{v}^\tau_0, \mathsf{v}^\tau_1, \ldots\}$ and *recursion (memory) variables*, $\mathsf{RecVars}_\tau = \mathsf{RecV} = \{\mathsf{r}^\tau_0, \mathsf{r}^\tau_1, \ldots\}$.

Definition 1 (Terms)**.** $\mathsf{Terms} = \mathsf{Terms}(\mathrm{L}^{\lambda}_{\mathrm{ar}}) = \cup\, \mathsf{Terms}_\tau$ *where, for each* $\tau \in \mathsf{Types}$, Terms_τ *is the set of the terms of type* τ*, defined by* (2a)–(2g)*, in a typed style of Backus-Naur Form (TBNF), and notations for type assignments,* $A : \tau$ *and* A^τ*:*

$$A :\equiv \mathsf{c}^\tau : \tau \mid x^\tau : \tau \qquad (\textit{constants and variables}) \tag{2a}$$

$$\mid B^{(\sigma\to\tau)}(C^\sigma) : \tau \qquad (\textit{application terms}) \tag{2b}$$

$$\mid \lambda(v^\sigma)(B^\tau) : (\sigma \to \tau) \qquad (\lambda\textit{-abstraction terms}) \tag{2c}$$

$$\mid A^{\sigma_0}_0 \ \mathsf{where} \ \{\, p^{\sigma_1}_1 := A^{\sigma_1}_1, \ldots, p^{\sigma_n}_n := A^{\sigma_n}_n \,\} : \sigma_0 \qquad (\textit{recursion terms}) \tag{2d}$$

$$\mid \wedge(A_2^\tau)(A_1^\tau) : \tau \mid \vee (A_2^\tau)(A_1^\tau) : \tau \mid \rightarrow (A_2^\tau)(A_1^\tau) : \tau \quad (\textit{conjunction} \; / \; \textit{disjunction} \; / \; \textit{implication terms}) \tag{2e}$$

$$\mid \neg(B^\tau) : \tau \qquad (\textit{negation terms}) \tag{2f}$$

$$\mid \forall(v^\sigma)(B^\tau) : \tau \mid \exists(v^\sigma)(B^\tau) : \tau \qquad (\textit{logic quantifier terms}) \tag{2g}$$

given that

(1) $\mathsf{c} \in K_\tau = \mathsf{Consts}_\tau$, $x \in \mathsf{PureV}_\tau \cup \mathsf{RecV}_\tau$, $v \in \mathsf{PureV}_\sigma$
(2) In (2d)*: for* $i = 1, \ldots, n$, $p_i \in \mathsf{RecV}_{\sigma_i}$ *are pairwise different recursion (memory) variables, such that the sequence of assignments* $\{ p_1^{\sigma_1} := A_1^{\sigma_1}, \ldots, p_n^{\sigma_n} := A_n^{\sigma_n} \}$ *is acyclic by the Acyclicity Constraint (AC)*
(3) In (2e)–(2g), $\tau \in \{ \mathsf{t}, \widetilde{\mathsf{t}} \}$ *are for state-independent and state-dependent truth values*

Acyclicity Constraint (AC) The sequence of assignments (3a) is *acyclic* iff there is a function $\mathsf{rank} : \{p_1, \ldots, p_n\} \rightarrow \mathbb{N}$, such that:

$$\{ p_1^{\sigma_1} := A_1^{\sigma_1}, \ldots, p_n^{\sigma_n} := A_n^{\sigma_n} \} \quad (n \geq 0) \tag{3a}$$

$$\text{if } p_j \text{ occurs freely in } A_i, \text{ then } \mathsf{rank}(p_i) > \mathsf{rank}(p_j) \tag{3b}$$

Without the AC, (2a)–(2d) define the language L_r^λ of full recursion, to which I add terms of the logic operators and quantifiers (2e)–(2g).

We say that a term A is *explicit* iff the constant where designating the recursion operator does not occur in it. A is a λ-*calculus term* iff it is explicit and no recursion variable occurs in it.

Denotational Semantics of the Logic Operators and Quantifiers The detailed denotational semantics of $\mathrm{L}_{\mathrm{ar}}^\lambda$ is presented in Moschovakis [3] and Loukanova [1]. For any given semantic structure $\mathfrak{A}$ having a semantic frame $\mathbb{T} = \{ \mathbb{T}_\sigma \mid \sigma \in \mathsf{Types} \}$ of typed domains $\mathbb{T}_\sigma$, and the set G of all variable valuations g in $\mathbb{T}$, the denotation function $\mathsf{den}^\mathfrak{A}(A)$ is defined by structural induction on the terms A in (2a)–(2d).

In this paper, I extend $\mathsf{den}^\mathfrak{A}(A)$ for terms of the form (2e)–(2g). For instance, the denotation of the state-dependent existential quantifier is:

$$\text{for } \tau = \widetilde{\mathsf{t}},\ \mathsf{den}^\mathfrak{A}\big(\exists(v^\sigma)(B^\tau)\big)(g) \colon \mathbb{T}_\mathsf{s} \rightarrow \mathbb{T}_\mathsf{t} \text{ is a function, such that:} \tag{4a}$$

$$\text{for every state } s \in \mathbb{T}_\mathsf{s}\text{: } \big[\mathsf{den}^\mathfrak{A}\big(\exists(v^\sigma)(B^\tau)\big)(g)\big](s) = 1 \text{ (true in } s) \tag{4b}$$

$$\text{iff there is } a \in \mathbb{T}_\sigma, \text{ in the semantic domain } \mathbb{T}_\sigma, \text{ such that: } \big[\mathsf{den}^\mathfrak{A}\big(B^\tau\big)(g\{ x := a \})\big](s) = 1 \tag{4c}$$

The set of the *immediate terms* consists of all terms of the form (5), for $p \in \mathsf{RecV}$, $u_i, v_j, \in \mathsf{PureV}$ $(i = 1, \ldots, n,\ j = 1, \ldots, m,\ m, n \geq 0)$, $V \in \mathsf{Vars}$:

$$T :\equiv V \mid p(v_1) \ldots (v_m) \mid \lambda(u_1) \ldots \lambda(u_n) p(v_1) \ldots (v_m) \tag{5}$$

Every term A that is not immediate is called *proper*. Intuitively, a term is immediate if its denotation $\mathsf{den}(A)$ is obtained by the values provided via the variable valuations $g \in G$, without any algorithmic steps of computations.

Algorithmic Semantics The *algorithmic meaning* of a proper $A \in \mathsf{Terms}$, i.e., a non-immediate, algorithmically meaningful term, is designated by $\mathsf{alg}(A)$ and is determined by its canonical form $\mathsf{cf}(A)$. Informally, for each meaningful term A, the *algorithm* $\mathsf{alg}(A)$ for computing its denotation $\mathsf{den}(A)$ consists of computations provided by the basic parts A_i of $\mathsf{cf}(A) \equiv A_0$ where $\{p_1 := A_1, \ldots, p_n := A_n\}$, by their structural rank, by recursive iteration.

For every $A \in \mathsf{Terms}$, $\mathsf{cf}(A)$ is obtained from A by the reduction calculus of $\mathrm{L}^{\lambda}_{\mathrm{ar}}$.

2 Reduction Rules of Extended $\mathbf{L}^{\boldsymbol{\lambda}}_{\mathbf{ar}}$

I designate the logic operators as specialised, logic constants. By that, I classify the reduction rules for the terms (2e)–(2f), as special cases of the reduction rule for application terms. In this section, I extend the set of the $\mathrm{L}^{\lambda}_{\mathrm{ar}}$-reduction rules introduced in [3], by adding the reduction rules (ξ) for the quantifier terms (2g).

Congruence The congruence relation between terms is the closure on renaming bound variables (pure and recursion), without causing variable collisions, and on reordering of recursion assignments:

$$\text{If } A \equiv_c B, \text{ then } A \Rightarrow B \tag{cong}$$

Transitivity If $A \Rightarrow B$ and $B \Rightarrow C$, then $A \Rightarrow C$ (trans)

Compositionality Replacement of sub-terms with correspondingly reduced ones respects the term structure by the definition of the term syntax:

$$\text{If } A \Rightarrow A' \text{ and } B \Rightarrow B', \text{ then } A(B) \Rightarrow A'(B') \tag{comp-ap}$$

$$\text{If } A \Rightarrow B, \text{ and } \xi \in \{\,\lambda, \exists, \forall\,\}, \text{ then } \xi(u)(A) \Rightarrow \xi(u)(B) \tag{comp-lq}$$

$$\begin{gathered}\text{If } A_i \Rightarrow B_i, \text{ for } i = 0, \ldots, n, \text{ then}\\ A_0 \;\mathsf{where}\; \{\, p_1 := A_1, \ldots, p_n := A_n \,\} \Rightarrow B_0 \;\mathsf{where}\; \{\, p_1 := B_1, \ldots, p_n := B_n \,\}\end{gathered} \tag{comp-rec}$$

Head Rule Given that $p_i \neq q_j$ and p_i does not occur freely in B_j

$$\begin{aligned}&\big(A_0 \;\mathsf{where}\; \{\, \overrightarrow{p} := \overrightarrow{A} \,\}\big) \;\mathsf{where}\; \{\, \overrightarrow{q} := \overrightarrow{B} \,\}\\ &\Rightarrow A_0 \;\mathsf{where}\; \{\, \overrightarrow{p} := \overrightarrow{A},\; \overrightarrow{q} := \overrightarrow{B} \,\}\end{aligned} \tag{head}$$

Bekič-Scott Rule Given that $p_i \neq q_j$ and q_j does not occur freely in A_i

$$\begin{aligned}&A_0 \;\mathsf{where}\; \{\, p := \big(B_0 \;\mathsf{where}\; \{\, \overrightarrow{q} := \overrightarrow{B} \,\}\big), \overrightarrow{p} := \overrightarrow{A} \,\}\\ &\Rightarrow A_0 \;\mathsf{where}\; \{\, p := B_0, \overrightarrow{q} := \overrightarrow{B},\; \overrightarrow{p} := \overrightarrow{A} \,\}\end{aligned} \tag{B-S}$$

Recursion-Application Rule Given that p_i does not occur freely in B

$$\big(A_0 \;\mathsf{where}\; \{\, \overrightarrow{p} := \overrightarrow{A} \,\}\big)(B) \Rightarrow A_0(B) \;\mathsf{where}\; \{\, \overrightarrow{p} := \overrightarrow{A} \,\} \tag{recap}$$

Application Rule Given that $B \in \mathsf{Terms}$ is proper and $b \in \mathsf{RecV}$ is fresh

$$A(B) \Rightarrow\ A(b) \text{ where } \{ b := B \} \tag{ap}$$

λ and Quantifier Rules Let $\xi \in \{ \lambda, \exists, \forall \}$

$$\begin{aligned} &\xi(u)\,(A_0 \text{ where } \{ p_1 := A_1, \dots, p_n := A_n \}) \\ \Rightarrow\ &\xi(u)\, A'_0 \text{ where } \{ p'_1 := \lambda(u)\, A'_1, \dots, p'_n := \lambda(u)\, A'_n \} \end{aligned} \tag{ξ}$$

given that for every $i = 1, \dots, n$, $p'_i \in \mathsf{RecV}$ is a fresh recursion (memory) variable, and A'_i is the result of the replacement of all the free occurrences of $p_1, \dots, p_n$ in A_i with $p'_1(u), \dots, p'_n(u)$, respectively, i.e.:

$$A'_i \equiv A_i\{p_1 :\equiv p'_1(u), \dots, p_n :\equiv p'_n(u)\} \equiv A_i\{\overrightarrow{p} :\equiv \overrightarrow{p'(u)}\} \tag{7}$$

Theorem 1 (Canonical Form Theorem). *See [1]–[3]. For every term $A \in \mathsf{Terms}$, there is a term $\mathsf{cf}(A)$, called the canonical form of A, such that:*

$$\mathsf{cf}(A) \equiv A_0 \text{ where } \{ p_1 := A_1, \dots, p_n := A_n \} (n \geq 0)$$

(1) $A \Rightarrow \mathsf{cf}(A)$
(2) for every B, if $A \Rightarrow B$ and B is irreducible, then $B \equiv_c \mathsf{cf}(A)$, i.e., $\mathsf{cf}(A)$ is the unique, up to congruence, term to which A can be reduced
(3) $\mathsf{FreeV}(\mathsf{cf}(A)) = \mathsf{FreeV}(A)$; $\mathsf{Consts}(\mathsf{cf}(A)) = \mathsf{Consts}(A)$

Proof. It is long and outlined in Moschovakis [3]. A version is given in Loukanova [1]. $\square$

Coordinated Predication: a class of sentences with coordinated VPs

$$[\Phi_j]_{\text{NP}}\ \big[[\Theta_L \text{ and } \Psi_H]\ [W_w]_{\text{NP}}\big]_{\text{VP}} \xrightarrow{\mathsf{render}} \underbrace{\lambda x_j \big[\lambda y_w \big(L(x_j)(y_w) \wedge H(x_j)(y_w)\big)(w)\big](j)}_{\text{algorithmic pattern with memory parameters } L,\, H,\, w,\, j} \tag{8}$$

Specific Instantiations of Parametric Algorithms, e.g., (8), by (9c)–(9d):

$$[\text{John}]_j \text{ loves and honors } [\text{his}]_j \text{ wife.} \xrightarrow{\mathsf{render}} A \tag{9a}$$

$$A \equiv \lambda x_j \big[\lambda y_w \big(\mathit{loves}(y_w)(x_j) \wedge \mathit{honors}(y_w)(x_j)\big)\big(\mathit{wife}(x_j)\big)\big](\mathit{john}) \tag{9b}$$

$$\Rightarrow \cdots \Rightarrow \mathsf{cf}(A) \equiv \underbrace{\lambda x_j \big[\lambda y_w \big(L''(x_j)(y_w) \wedge H''(x_j)(y_w)\big)(w'(x_j))\big](j)}_{\text{algorithmic pattern with memory parameters } L'',\, H'',\, w',\, j} \tag{9c}$$

$$\begin{aligned} \text{where } \{ &L'' := \lambda x_j \lambda y_w\, \mathit{loves}(y_w)(x_j), \\ &\underbrace{\begin{aligned} H'' &:= \lambda x_j \lambda y_w\, \mathit{honors}(y_w)(x_j), \\ w' &:= \lambda x_j \mathit{wife}(x_j),\ j := \mathit{john} \end{aligned}}_{\text{instantiations of memory } L'',\, H'',\, w',\, j} \} \end{aligned} \tag{9d}$$

Logic Quantifiers and Reductions with Quantifier Rules: Explicit logic terms, e.g., (10a), can be reduced to recursive canonical forms, (10c). Assume that *cube*, $large_0 \in$ $\mathsf{Consts}_{(\tilde{\mathsf{e}} \to \tilde{\mathsf{t}})}$. and $large \in \mathsf{Consts}_{((\tilde{\mathsf{e}} \to \tilde{\mathsf{t}}) \to (\tilde{\mathsf{e}} \to \tilde{\mathsf{t}}))}$ is a modifier.

$$\text{Some cube is large} \xrightarrow{\mathsf{render}} B \equiv \exists x(cube(x) \wedge large_0(x)) \tag{10a}$$

$$\Rightarrow \exists x((c \wedge l) \text{ where } \{\, c := cube(x),\ l := large_0(x) \,\}) \quad 2\text{x(ap) to } \wedge;\ \text{(comp-lq)} \tag{10b}$$

$$\Rightarrow \underbrace{\exists x(c'(x) \wedge l'(x))}_{B_0 \text{ algorithmic pattern}} \text{ where } \{\, \underbrace{c' := \lambda(x)(cube(x)),\ l' := \lambda(x)(large_0(x))}_{\text{instantiations of memory } c',\, l'} \,\} \ (\xi) \tag{10c}$$

Proposition 1. *The* $\mathrm{L}^{\lambda}_{\mathrm{ar}}$*-terms* $C \approx \mathsf{cf}(C)$ *in (11a)–(11d), similarly to many other* $\mathrm{L}^{\lambda}_{\mathrm{ar}}$*-terms, are not algorithmically equivalent to any explicit term. Thus,* $\mathrm{L}^{\lambda}_{\mathrm{ar}}$ *is a strict, proper extension of Montagovian semantics.*

$$\text{Some cube is large} \xrightarrow{\mathsf{render}} C \equiv \exists x \big[\underbrace{c'(x) \wedge large(c')(x)}_{E_0}\big] \text{ where } \{\, c' := cube \,\} \tag{11a}$$

$$\Rightarrow \underbrace{\exists x \big[\big(c'(x) \wedge l\big) \text{ where } \{\, l := large(c')(x) \,\}\big]}_{E_1} \text{ where } \{\, c' := cube \,\} \tag{11b}$$

by (ap) to $\wedge$ of E_0; (comp-lq); (comp-rec)

$$\Rightarrow \underbrace{\big[\exists x\big(c'(x) \wedge l'(x)\big) \text{ where } \{\, l' := \lambda(x)\big(large(c')(x)\big) \,\}\big]}_{E_2} \text{ where } \{\, c' := cube \,\} \tag{11c}$$

$$\Rightarrow \underbrace{\exists x\big(c'(x) \wedge l'(x)\big)}_{C_0 \text{ an algorithmic pattern}} \text{ where } \{\, \underbrace{c' := cube,\ l' := \lambda(x)\big(large(c')(x)\big)}_{\text{instantiations of memory } c',\, l'} \,\} \equiv \mathsf{cf}(C) \tag{11d}$$

by (head), from (11c); (cong)

Motivation for the Type Theory $\mathrm{L}^{\lambda}_{\mathrm{ar}}$*: Provides Algorithmic Patterns.* Memory variables in $\mathrm{L}^{\lambda}_{\mathrm{ar}}$-terms can be instantiated by the corresponding canonical forms, depending on the specific areas of applications and domain specific texts, e.g., as in (10c) and (11d); and (8) as in (9d).

Motivation for $\mathrm{L}^{\lambda}_{\mathrm{ar}}$ *with Logical Operators and Standard Quantifiers: Reasoning and Semantic Inferences.* Canonical forms can be used for reasoning and inferences of semantic information by automatic provers and prove assistants.

In the full paper, I shall extend the formal language of γ^*-reduction calculus, see Loukanova [2], by the logic operators and standard quantifiers.

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Deriving formal semantic representations from dependency structures
— extended abstract —

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1 introduction

Dependency grammars provide an interesting alternative to phrase structure grammars. They derive from a long linguistic tradition [3], and are gaining more and more interest in the computational linguistic international community [6]. One of their advantages is that dependency parsing appears to be more robust than constituency parsing. Indeed, while parsing an agrammatical sentence with a phrase structure grammar usually leads to a failure, parsing it with a dependency grammar can result in an incomplete dependency structure that nevertheless carries some semantic information.

Dependency grammars, however, do not seem suitable for a formal semantic treatment, in the tradition of Montague [5]. Formal semantics [2], being compositional, relies heavily on the notion of constituent, a notion that does not appear explicitly within dependency structures.

A possible remedy to this this situation is to normalize the dependency structures in order to recover an implicite notion of constituent (see [7], for instance). This approach, however, is not robust in the sense that it does not allow for the interpretation of partial dependency structures. The goal of this paper is to remedy this problem by laying the grounds for a new formal theory of dependency semantics, in the spirit of Montague.

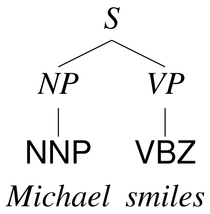
2 The basic concept

Consider the following simple sentence:

(1) *Michael smiles*

Parsing it with a phrase structure grammar would yield a constituency parse tree akin to the following one[1]:

[1] All the parse trees and the constituency structures occurring in this abstract have been obtained using the Stanford parser



Following Montague [4], one may take advantage of the above parse tree in order to derive the truth-conditional meaning of sentence (1). To this end, let us write $\textsc{s}$, $\textsc{np}$, and $\textsc{vp}$ for the semantic interpretations of the syntactic categories *S*, *NP*, and *VP*. As usual, one posits:

$$\begin{aligned} \textsc{s} &= \mathbf{t} \\ \textsc{vp} &= \mathbf{e} \to \mathbf{t} \\ \textsc{np} &= \textsc{vp} \to \textsc{s} = (\mathbf{e} \to \mathbf{t}) \to \mathbf{t} \end{aligned}$$

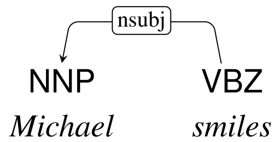
Then, one assigns the following lexical semantic recipes to *Michael* and *smiles*:

$$\begin{aligned} \textsc{michael} &= \lambda p.\, p\,\mathbf{m} : \textsc{vp} \to \textsc{s} \\ \textsc{smile} &= \lambda x.\, \mathbf{smile}\,x : \textsc{vp} \end{aligned}$$

This allows one to compute the the truth-conditional semantics of sentence (1) by reducing the corresponding λ-term:

(2) $\textsc{michael}\,\textsc{smile} \twoheadrightarrow_\beta \mathbf{smile}\,\mathbf{m}$

Now, we want to apply the same kind of technique to dependency grammars, i.e, to derive the truth-conditional semantics of sentence (1) form the following dependency structure:

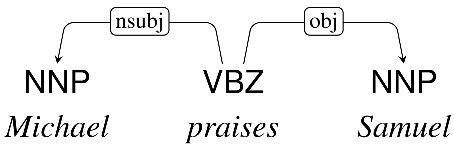


The solution we develop in this paper is based on a simple idea, which consists in assigning a semantic role to the dependency relations, and computing the desired semantics from a term akin to $\mathsf{nsubj}\,(\textsc{smile}, \textsc{michael})$ (or simply, $\mathsf{nsubj}\ \textsc{smile}\ \textsc{michael}$, using the λ-calculus notation). For our current example, it suffices to let $\mathsf{nsubj} = \lambda vn.\, n\, v$. However, as we will see, this interpretation is too simple.

3 The coherence requirement

In pursuing the basic idea we sketched in the previous section, we soon run into an obstacle. There is indeed no canonical way of representing a dependency structure as a term. Consider, for instance, the following sentence together with its dependency structure:

(3) *Michael praises Samuel*



There is in fact two ways of encoding the above dependency structure as a term:

(4) a. $\textsf{nsubj}\,(\textsf{obj}\ \textsc{praise}\ \textsc{samuel})\ \textsc{michael}$
b. $\textsf{obj}\,(\textsf{nsubj}\ \textsc{praise}\ \textsc{michael})\ \textsc{samuel}$

One could try to circumvent this difficulty by preferring one of these representations to the other, but such a choice would be arbitrary. Moreover, the resulting solution would not be robust in the sense that it would not allow for the interpretation of partial dependency structures. Consequently, we require the coherence condition that both terms (4-a) and (4-b) must yield the same semantic interpretation.

In order to satisfy this coherence condition, we adopt a Neo-Davisdsonian event semantics, and interpet a sentence as a set of sets of events, as suggested by Champolion [1]. This gives rise to the following semantic interpretation:

$$\textsc{gs} = (\mathbf{v} \to \mathbf{t}) \to \mathbf{t}$$

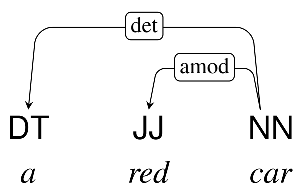
$$\begin{aligned}
\textsc{michael} &= \lambda p.\, p\,\mathbf{m} : \textsc{np} \\
\textsc{samuel} &= \lambda p.\, p\,\mathbf{s} : \textsc{np} \\
\textsc{praises} &= \lambda p.\, \exists e.\, (\mathbf{praise}\,e) \wedge (p\,e) : \textsc{gs}
\end{aligned}$$

$$\begin{aligned}
\textsf{nsubj} &= \lambda vn.\, \lambda p.\, n\,(\lambda x.\, v\,(\lambda e.\, (\mathbf{agent}\,e\,x) \wedge (p\,e))) : \textsc{gs} \to \textsc{np} \to \textsc{gs} \\
\textsf{obj} &= \lambda vn.\, \lambda p.\, n\,(\lambda x.\, v\,(\lambda e.\, (\mathbf{theme}\,e\,x) \wedge (p\,e))) : \textsc{gs} \to \textsc{np} \to \textsc{gs}
\end{aligned}$$

4 Interpreting the noun phrases

Montagovian semantics assigns to the (common) nouns the semantic category $\textsc{n} = \mathbf{e} \to \mathbf{t}$. It assigns to the adnominal modifiers, such as the adjectives, the category $\textsc{adj} = \textsc{n} \to \textsc{n}$, and to the determiners, the category $\textsc{det} = \textsc{n} \to \textsc{np}$. This approach is not directly transferable to the case of dependency structures. Consider indeed the folowing noun phrase and its associated dependency structure:

(5) *a red car*



As a consequence of the coherence condition, the following expressions must be assigned the same semantic type:

(6)
a. CAR
b. amod CAR RED
c. det CAR A
d. det (amod CAR RED) A
e. amod (det CAR A) RED

More generally, if dep is the semantic recipe associated to a dependency edge $\boxed{\text{dep}}$, we must have:

$$\mathsf{dep} : \alpha \to \beta \to \alpha$$

where α is the semantic type assigned to the source of the edge, and β, the semantic type assigned to its target.

A way of satisfying the above requirement is to parametrize the type assigned to the head of a dependency relation with the types assigned to all its possible dependents. In the case of the expressions listed in (6), this type is then the following one:

$$\textsc{gnp} = \textsc{det} \to \textsc{adj} \to \textsc{np}$$

Accordingly, the semantic recipes associated to the lexical items and dependency relations are as follows:

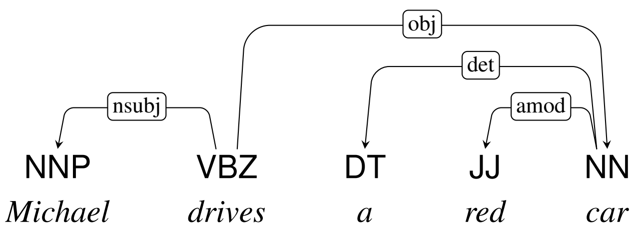
$$\begin{aligned} \textsc{a} &= \lambda pq.\, \exists x.\, (p\, x) \wedge (q\, x) \,:\, \textsc{det} \\ \textsc{red} &= \lambda nx.\, (n\, x) \wedge (\mathbf{red}\, x) \,:\, \textsc{adj} \\ \textsc{car} &= \lambda da.\, d\, (a\, \mathbf{car}) \,:\, \textsc{gnp} \end{aligned}$$

$$\begin{aligned} \mathsf{amod} &= \lambda na.\, \lambda db.\, n\, d\, (\lambda z.\, b\, (a\, z)) \,:\, \textsc{gnp} \to \textsc{adj} \to \textsc{gnp} \\ \mathsf{det} &= \lambda nd.\, \lambda ea.\, n\, d\, a \,:\, \textsc{gnp} \to \textsc{det} \to \textsc{gnp} \end{aligned}$$

5 Revisiting the subject and object dependencies

The typing principle we posited in the previous section must be propagated throughout the grammar. Therefore, the type assigned to nsubj and obj should no longer be GS $\to$ NP $\to$ GS but GS $\to$ GNP $\to$ GS. Similarly, the semantic type assigned to a proper name should be GNP rather than NP. let us illustrate this with a last example. Consider the following sentence:

(7) *Michael drives a red car*



This example can be handled using the following semantic recipes, which implement the principles we have discussed in this abstract:

$$
\begin{aligned}
\mathrm{A} = \mathrm{SOME} &= \lambda pq.\, \exists x.\, (p\, x) \wedge (q\, x) : \mathrm{DET} \\
\mathrm{RED} &= \lambda nx.\, (n\, x) \wedge (\mathbf{red}\, x) : \mathrm{ADJ} \\
\mathrm{CAR} &= \lambda da.\, d\, (a\, \mathbf{car}) : \mathrm{GNP} \\
\mathrm{MICHEL} &= \lambda dap.\, p\, \mathbf{m} : \mathrm{GNP} \\
\mathrm{DRIVE} &= \lambda p.\, \exists e.\, (\mathbf{drive}\, e) \wedge (p\, e) : \mathrm{GS}
\end{aligned}
$$

$$
\begin{aligned}
\textsf{amod} &= \lambda na.\, \lambda db.\, n\, d\, (\lambda z.\, b\, (a\, z)) : \mathrm{GNP} \to \mathrm{ADJ} \to \mathrm{GNP} \\
\textsf{det} &= \lambda nd.\, \lambda ea.\, n\, d\, a : \mathrm{GNP} \to \mathrm{DET} \to \mathrm{GNP} \\
\textsf{nsubj} &= \lambda vn.\, \lambda p.\, n\, \mathrm{SOME}\, (\lambda x.\, x)\, (\lambda x.\, v\, (\lambda e.\, (\mathbf{agent}\, e\, x) \wedge (p\, e))) : \mathrm{GS} \to \mathrm{NP} \to \mathrm{GS} \\
\textsf{obj} &= \lambda vn.\, \lambda p.\, n\, \mathrm{SOME}\, (\lambda x.\, x)\, (\lambda x.\, v\, (\lambda e.\, (\mathbf{theme}\, e\, x) \wedge (p\, e))) : \mathrm{GS} \to \mathrm{NP} \to \mathrm{GS}
\end{aligned}
$$

The reader may then check that the four possible expressions that encode the above dependency structure yield all the same semantic interpretation[2] of sentence (7), namely:

$$\lambda f.\, \exists x.\, (\mathbf{car}\, x) \wedge (\mathbf{red}\, x) \wedge (\exists e.\, (\mathbf{drive}\, e) \wedge (\mathbf{agent}\, e\, \mathbf{m}) \wedge (\mathbf{theme}\, e\, x) \wedge (f\, e))$$

6 Conclusions

We have discussed and elaborated some principles that provide the basis for a formal theory of dependency semantics. The resulting system satisfies several interesting properties that the format of this extended abstract does not allow us to illustrate further. In particular, the toy semantic grammar that supports our last example allows incomplete dependency structures to be assigned semantic interpretations, showing therefore some robustness. It also provides an effective treatment of scope ambiguities.

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[2] up to conjunction commutativity

Modal Reasoning and Theorizing in Quantified Modal Logic

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Logicians have developed various forms of quantified modal logic and its semantics. In many of these logics, certain metaphysical facts and principles, and typically those involving singular names and other linguistic features, are endorsed as theorems or necessary truths. For instance, Hesperus is necessarily identical with Phosphorus, or all true identities are necessarily true. This talk concerns how logic and semantics can represent a cognizer's reasoning about these facts and principles. On the one hand, many philosophers maintain that metaphysical facts of this type can be necessary *a posteriori*. Most of the semantics they propose, on the other hand, have these facts (or metaphysical principles underlying them) built into the mathematical makeup. Therefore, while these semantics deem those facts necessarily true, they cannot account for their aposteriority. I will take an approach based on intensional logic that treats all terms, predicates, and quantifiers as uniformly intensional. Augmenting it with epistemic logic, I will demonstrate how this logic can represent metaphysical facts and principles as *a posteriori* facts and substantial principles that a cognizer can learn and use in their modal reasoning and theorizing. In a certain sense, this talk attempts to draw a new line of distinction between logic and theory of modal metaphysics.

Factivity Alternation Types and Compensatory Prosodic Focus Marking

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1. Introduction

This talk explores different cross-linguistic factivity alternation types to see how different languages mobilize different means of representation for factivity alternation in epistemic/doxastic attitudes. Altaic languages including Korean show factivity alternation of 'know' (Japanese alone has no alternation of 'know') and other cognitive attitude verbs such as 'remember,' 'recognize,' 'understand,' etc. by distinct complement endings (Lee 1978, Lee 2019). Ch(inese) is the least alternating language, with mostly strictly factive epistemic attitude verbs, including the representative one 知道[zhidao] 'know,' which does not reveal any alternation signs ('recognize,' 'understand' are also factives with no alternation). The verb 记得 [jide] 'remember,' in contrast, is an alternation verb with no surface complement structure differentiation (Lee 2021). Then, how are the two semantic alternants of the verb 'remember' with no complementizers detected? I argue that it is by means of compensatory prosodic focus marking, by which the embedding verb part is focused in contrast with the factively presupposed unfocused complement part. This verbal focus marking occurs in compensation with the unrealized covert 'fact' head noun in apposition with its complement content. Such compensation **occurs** also occurs when alternation-marking complement case endings delete in Korean (Lee 2020, cf. Jeong 2021). E(nglish) is a moderately alternating language, with non-factive alternants occurring in some non-veridical contexts such as negative, interrogative, *before*, conditional, and a denial context such as *but --- not*, (in which contexts non-factive complement marking may occur in Altaic as well). The interrogative *whether* complementizer with P or not P is typically presuppositional, conceptually co-related to *know*, as in *remember*. If lexically or conceptually negated as in *moru-* (K(orean) 'not know') and *forget*, their complement presupposition is blocked. Preferential attitudes such as *hope* and *fear* can take *whether* cross-linguistically, which even engender expletive negation in K (and J(apanese)). The counterfactual attitude 'imagine whether' is endorsed only by a modal/futuristic/conditional complement cross-linguistically (Lee 2022, Liefke 2022). Overall, complements determine factivity.

2. Complement Structures for Factivity Alternation

In Altaic languages with SOV, center-embedded factively presupposed complements have nominal/DP endings (with ACC markers), whereas non-factive complements have REPORT C regularly (in Uyghur, and Manchurian as well, Lee (2019)).

(1) a. Bat [Mia –giin yav-san-iig] mede-j baina Factive (Mongolian)
B M-GEN leave-NPST-ACC know ST
'Bat knows that Mia left.' [[-j baina: ST = result state]]
b. Ken [Mia-g yav-san gej] mede-j baina Non-factive (Mongolian)
K M-ACC leave-PST REPORT know ST
'Ken non-factively knows [believes] that Mia left.'

(2) a. Da [Sue-nun git–tiğin-i] bil-iyor Factive (Turkish)
D S-GEN leave-pstN-ACC know-PRES.3Sg
'Da knows that Sue left.' (Sue's having left)
b. Da [Sue git-ti-diye] bil-iyor D S-NOM leave-PST-REPORT know-PRES-3rdSg
'Da non-factively knows that Sue left' Non-factive (Turkish)

(3) a. Mia-nun [Hia-ka ttena-n kes-ul] al-ko iss-ta Factive (Korean)

M-TOP H-NOM leave-ADNpst ProFactN-ACC 'know'-ST-DEC
'Mia knows that Hia left.' [ADNpst: ADNominal with past; ST=-ko iss-: result state]
b. ?Mia-nun [Hia-ka ttena-ess-ta-ko] al-ko iss-ta Non-factive (Korean)
M-TOP H-NOM leave-PST-DEC-C 'know'-ST-DEC (Lit.)
'Mia non-factively knows [i.e., believes with evidence] Hia left.'
(C=REPORTative complementizer; not in the reportative evidential meaning)

In Chinese, non-Altaic, 知道[zhidao]'know,' 'understand,' and 'recognize' are only factive but 记得[jide]'remember' is a factivity alternation verb, as follows:

(4) a. Ta **jide**/**bu jide** [jintian shi faxinri]. (the complement is presupposed) Factive (Chinese)
he remember/not remember today is payday
'He remembers/does not remember today's payday.' [Yuan 2020 argues *jide* is only factive with no alternation]
b. Ta jide [**jintian** shi faxinri] Qishi jintian bu shi faxinri. Non-factive (Chinese)
he remember today is payday in fact today not is payday
'He (falsely) remembers today's payday. In fact, today is not payday.' (non-factive)

The factive and non-factive complements [jintian shi faxinri] 'today is payday' have the same complement clause form with bare C. 60 native speakers didn't mention intonation in their survey responses but most responded that they feel the presence of (*ting-*)*shuo* '(hear-)say' in front of the complement. It functions as a grammaticalized C (confirmed by Jim Huang, via e-mail, 2022). This 'say' C for non-factive complements is common with Altaic and covertly English. I asked several native speakers whether they feel intonation differences between the factive vs. non-factive *jide* sentences and they said 'yes.' So, I conducted the intonation experiment (with PRAAT), the result of which is as follows, as expected. The factively presupposed complement has no focus and the main V is focused on Fig. 1 below.

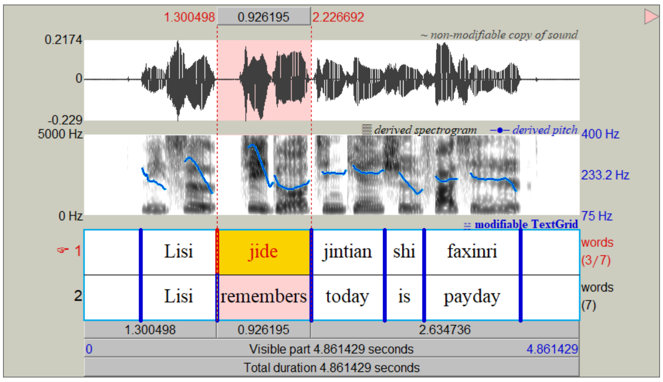

Figure 1 The main V *jide* is focal and high.

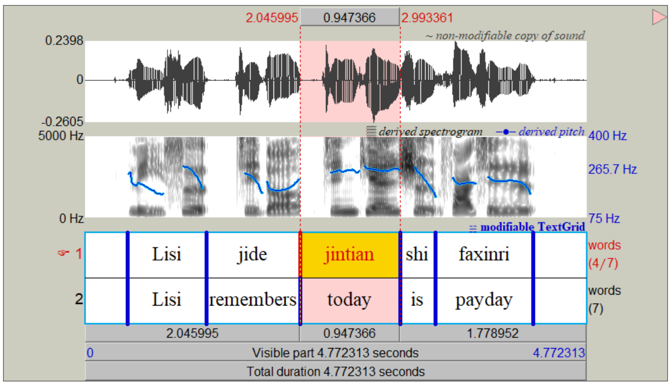

Figure 1 The complement part *jintian* is focal and high.

In contrast, the complement element *jintian* 'today' is focused on Fig.2 above. The above contrast is due to **the compensatory focus marking (CFM)**, I argue, in compensation with the **covert** conceptual, structural representation of the FACT DP with its appositional, presuppositional proposition. The focus marking arises when there occurs rivalry between factive vs. non-factive alternation in particular. The main attitude verb is foregrounded with its presupposition backgrounded, non-presupposed elements foregrounded. This happens cross-linguistically. Let's consider the often-cited English example (Beaver 2010):

(5) a. If the T.A. DISCOVERS that your work is plagiarized, I will be forced to notify the dean.
b. If the T.A. discovers that your work is PLAGIARIZED, I will be forced to notify the dean.

In case a conditional operator precedes an epistemic attitude verb, presupposition projection depends, I argue, on the location of the focus: If the epistemic verb DISCOVERS itself is focused as in (5a), this factive alternant gets its non-focal complement presupposition triggered. In contrast, if a part PLAGIARIZED of the complement is foreground focused as in (5b), then the complement content is not presupposed. The main verb focus in (5a) is in compensation with the covert FACT complement. In (5b), in a conditional clause, the complement element PLAGIARIZED is foreground focused, and it receives a non-factive reading. In this case, Altaic complements get the overt REPORT C. **CFM** occurs if alternation rivalry arises.

In Korean, another ProFact noun *cwul* gets factivity alternating grammatical markings of ACC -*ul* for the factive complement of 'know' vs. DIRECTIONAL -*lo* for the non-factive complement of 'know'. In conversational Korean, however, these distinguishing case markers are easily deleted and the bare *cwul* produces factivity ambiguity. Here, the **CFM** intervenes: if the ProFact N occurs with no ACC, then the higher embedding 'know' is focused to get its factive reading (6a) but if the same N with no ProFact function because of the oblique DIRECTIONAL postposition/case -*lo*, then a part or the whole of the complement is focused to receive its non-factive reading (6b). If the main V remains and the complement is deleted, as "na al-a" in K or "I know" in E, it is factive, not non-factive (impossible for 'believe').

(6) a. Ken-un [Mia-ka ttena-n cwul]-ø AL-A. b. Ken-un [MIA-ka ttena-n cwul]-ø al-a.
K -TOP M-NOM leave-C ProFact N know K-TOP M -NOM leave-C N know

Examine the English example of non-factive *know* in the context of *before*, which is an anti-veridical operator, not an alternating context, below in (7a) and compare it with other factivity alternation languages such as K (Altaic), and factive only Ch (non-Altaic) and J. The only interpretation of (7a) in E, is its non-factive reading because of the anti-veridical operator *before.* The non-factive *knew* has a covert SAY REPORTative C associated with 'that,' so the main V cannot be focused.

(7) a. Medieval Koreans **knew** that Ch characters *were* the best before Hangul was invented.
b. cwungsei hankwukin-tul-un Hangul-i changcey-toyki cen-ey-nun [Hanca-ka choyko-i
M K -PL-TOP H -NOM invent become before-TOP H -NOM best-be
-n kes uro al-ass-ta
A(dn)C kes DIR know-PST-DEC **<by Non-F DIR complement ending>**

c. Zai Hanwen faming yiqian, zhongshiji de Hanguoren **renwei/yiwei**/*zhidao Hanzi shi.

at Korean letters invent before, Middle Age of Koreans thought/believed/#knew C characters are the best **<by different verb in Ch (and J), belief doxastic only>**

Another common non-factive context in English is the consecutive denial *but --- not.* Observe.

(8) Ken remembers that a hippo sang, but (in fact) no hippo sang.

In this context again, K (and other Altaic as well) uses the non-factive complement ending REPORT C (or DIRectional PP).

The polar interrogative *whether* complementizer with P or not P is typically presuppositional, conceptually correlated to *know*, as in *remember* (similarly, in Egré's *Vp* ⇒ *p* veridicality in declarative and White's *whether*-licensing *Generalization* V ('a predicate is responsive iff it is veridical'). Several epistemic verbs have the same ⇒ relation (Ziever 2022) like 'x *remembers* that p' ⇒'x *knows* that p' and the same ⇒ relation applies to the *whether* complement iff the complement is presuppositional. Preferential attitude predicates such as 'hope' and 'fear' take, I claim, the non-presuppositional *whether* complement with cautious polarity consideration and even engender **expletive negation** in Korean and Japanese. The negation ***anh***-, logically not required, occurs with modal(-futurity) in (9) in K. (Similarly in J).

(9) Mia-ka ipen-ey-nun [caki-ka iki-ci **anh**-ul-kka] himangha-n-ta
M -NOM this time-at-TOP self-NOM win-NEG-MOD-Q hope -PRES-DEC
'Mia hopes whether she may ((not$_{\text{expl}}$)) win this time.'

The rare case of counterfactual attitude predicate *imagine whether* will also be examined cross-linguistically (K, Ch, and Italian), to see why modal/conditional complement only is allowed, whereas the ProFact N *kes(-ul)* K/*koto(-o)* J is odd as a counterfactual attitude predicate.

3. Fact vs. REPORT C Semantics for Semantic Universal(s)

In line with Kiparsky and Kiparsky 1971, Kratzer 2006, 2015, and Schueler 2016, I analyze a factively presupposed complement as a complement with the FACT DP head noun (or at least with *that*$_F$ in English) and the **ProFact N** DP with *kes* in K/or *koto* in J. This **ProFact N** is equivalent to FACT, referring to the embedded clause content (like a pronoun) via internal perception and exemplification. Its adnominal C *–(nu)n* ('high pitch' in J) connects the propositional clause content in apposition to the **ProFact N**. In contrast, the (overt or covert) REPORT C, derived from 'say,' functions as C, searching for a higher non-factive attitude predicate. If it happens to hit higher epistemic verbs, they become non-factive doxastic verbs.

The FACT/**ProFact** DP composes with [[know$_F$]] and other epistemic verbs that entail [[know$_F$]] such as [[recognize$_F$]](⇒[[know$_F$]]), [[be-aware$_F$]](⇒[[know$_F$]]), [[remember$_F$]](⇒[[know$_F$]]), [[understand $_F$]] (⇒[[know$_F$]]), [[discover$_F$]](⇒[[know$_F$]]), [[realize$_F$]](⇒[[know$_F$]]), [[see (that)]](⇒[[know$_F$]]), etc.

The FACT/**ProFact** DP also composes with those higher embedding lexically negative, anti-veridical verbs that entail [[∼know$_F$]] such as [[moru-]]('not know,' K), [[forget$_F$]], [[ic-]] ('forget,' K), [[bu-jide]]('not-remember,' Ch)/忘记 [wàngjì] 'forget,' Ch), etc. (Lee 2019, Jeong 2021 for K). In this group, a wide scope negation is blocked and the factivity reading alone remains.

The verb [[forget$_F$]], is factive and its complement is presupposed, whereas the implicative verb [[forget$_{IMPL}$]] cannot have a presuppositional component; its construction is limited to the infinitive and involves volitional modality (as in action V). This implicative meaning is cross-linguistcally attested: K Ken-un mwun-ul camku-l kes-ul ic-ess-ta 'Ken forgot to lock the door'; J wasureru '(forget$_F$' or 'forget$_{IMPL}$' tense); Ch jide 'forget$_{IMPL}$' modal *yao*).

[[wonder]] has its ingredient of [[know$_F$]]) but because it is embedded by a bouletic modal [[want]] as in J shiri-**tai** 'know-**want**', implying 'not-know,' it takes the interrogative C *whether*.

Karttunen's (1977) thesis that verbs of communications (such as *tell, indicate, inform, disclose*, etc.) when used with the complementizer *whether* give rise to "truth conveying" operators meets some pragmatic objections (Tsohatzidis 1997).

4. Concluding Remarks

By dividing between FACT DP presuppositional and REPORT C CP non-preuppositional complement clauses, we can come up with factive vs. non-factive attitude predicates (with factivity alternation) by composition. Alternation (conceptual and structural), with no surface distinction, is compensated for by prosodic focus-marking intonation, if rivalry occurs, triggering or not triggering presupposition, along the positions in speech.

This way, we can approach the goal of attaining the semantic universal(s) of factivity vs. non-factivity alternation.

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The Discourse Function of Aspect in Japanese

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1 Introduction

Aspect in Japanese, particularly the presence of the *te iru* form and its absence (i.e., the non-*te iru* form), has mainly been studied on a single sentence basis. In order to get a more exact picture of the aspectual system of the language, this paper sheds light on how it works in discourse, specifically considering whether reference points (hereafter RP's) should be adopted for this purpose. As a theoretical framework, we rely on Segmented Discourse Representation Theory (SDRT; Asher and Lascarides 2003), which formalizes the discourse coherence.

2 Previous studies

Kamp and Reyle (1993; hereafter K&R), after Hinrichs (1986), apply event semantics to the elucidation of tense and aspect in English by specifying relationships of an event (represented as e) or a state (s) to a temporal location (t; the denotation of temporal adverbial phrases, which is hypothesized to be present even without them) and the utterance time (n). The temporal relationships are denoted, e.g., by '$<$' for the earlier/later relation, by '$\subseteq$' for inclusion, and by '$\circ$' for overlapping. They use an RP (Reichenbach 1947) to relate the temporal meanings of sentences. An event (e) establishes a new RP, which occurs after the old one, while a state (s) does not add a new RP, instead including the previous one.

Lascarides and Asher (1993; L&A) cover more complicated temporal relationships between eventualities than K&R by introducing, following Hobbs (1985), discourse relations (hereafter DR's), which capture a rhetorical role of an utterance by investigating how it relates to others. They solve inconsistencies between rules by giving priority to the most specific of the applicable defeasible rules in the nonmonotonic logic. They do away with RP's, directly establishing relationships between eventuality pairs by reference to a DR or an Aktionsart.

Asher and Lascarides (2003; A&L) give accounts of discourse understanding, similarly to L&A. The logical form of a discourse is constructed efficiently through the glue logic, which has only restricted access to various information sources. A&L don't offer a systematic treatment of tense and aspect, but do analyze some temporal relations as directly derived from DR's, as in L&A.

3 Interpretation of tense and aspect and an RP

We propose to adopt RP's for the interpretation of tense and aspect, in contrast to L&A and A&L, for the following reasons.

First, in a *te iru* sentence with a perfective meaning, a *ni wa*-marked temporal adverbial often indicates a limit by which the event is accomplished. Such a temporal adverbial clearly introduces an RP.

(1) Kinoo wa, go-ji *ni wa* **kitaku-shi te i** ta.
yesterday TPC five o'clock LIMIT come home-LV PTCL PERF PST
'I was home by five o'clock yesterday.'

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[c]Ritsumeikan Asia Pacific University

Likewise, a temporal adverbial or a noun phrase often introduces a discourse referent, which provides a basis for the temporal interpretation of the following part of the text, typically in the beginning of a story or embedded by a predicate for belief or speech.

On the other hand, for the lexical description of temporal adverbials with context-dependent meanings (e.g., *sono go* 'after that' and *zenjitsu* 'the previous day'), an RP is needed for the basis of interpretation.

Furthermore, a *te iru* sentence can occur alone without neighboring sentences, which leads to hypothesizing an implicit RP supported by the extralinguistic context.

Lastly, some of *te iru* sentences with the EXPERIENTIAL usage perform the role of an event in the discourse, but are depicted from the perspective of a certain temporal point (see Section 5). This kind of sentence can be accounted for only with the concept of RP.

These facts motivate us to establish RP's as discourse referents. In doing so, we have to integrate information not only from predicate meanings, but also from those of temporal adverbials, in distinction from K&R. Moreover, a task still remains for us to find a way to apply RP's to real texts with complicated text structures.

4 Continuous usage of *te iru* form

The usage of the *te iru* form has been traditionally classified into four types: the continuous, resultative, experiential, and collocations with verbs which are virtually adjectives. This section mainly discusses the continuous and later mentions the resultative. In both usages, RP's are brought forth by events and affect the interpretation of states. Let us see how the tense and aspect in text (2) are interpreted.

(2) [i]A kun wa, tadachini dooshi o kyuugoo-shi te,
NAME TITLE TPC immediately like-minded people ACC rally-LV PTCL
[ii]sutoraiki o hakat ta. [iii]Zengakkyuu no oosawagi ni nat ta.
strike ACC plan PST the whole class ADNM confusion CPL become PST
[iv]Watashi wa, kyoohu no tame ni wanawana **hurue te i** ta.
I TPC fear ADNM cause for quivering tremble PTCL CONT PST
'A immediately rallied students of like mind and planned a strike. The whole class was thrown into confusion. I was trembling all over for fear.'

Sentence (2.i) is analyzed as the Segmented Discourse Representation Structure (SDRS) tagged with π_1 in Figure 1. Only the relevant part of the meaning is shown.

Sentence (2.ii) is parsed likewise as π_2. If two SDRS's α and β stand in a certain DR in some constituent λ, and additionally it is from world knowledge assumed that events of the sort described by α lead to events of the sort described as β (i.e., if α *occasions* β), then the DR *Narration* is inferred by default, as stipulated by (3) (A&L). We constrain both the eventualities to be nonstative. *me* outputs the main eventuality of the relevant constituent, i.e., the eventuality introduced by the main verb in its head (A&L).

(3) $(?(\alpha, \beta.\lambda) \wedge occasion(\alpha, \beta) \wedge event(me(\alpha)) \wedge event(me(\beta))) > Narration(\alpha, \beta, \lambda)$

Defeasible Modus Ponens produces from this the inference that the DR *Narration* between π_1 and π_2. This and the following rule establish a relationship between the RP's of π_1 and π_2.

(4) $\phi_{Narration(\alpha,\beta,\lambda)} \Rightarrow natural\_sequence(rp(\alpha), rp(\beta))$

$r(eference\text{-})p(oint)$ is a function which outputs the RP of the SDRS it takes. Here is a tentative definition, which still needs prescriptions for other cases of temporal adverbials:

$$\pi_1: \begin{array}{|l|} \hline e_1\ t_1\ x\ y \\ \hline t_1 < n \\ e_1 \subseteq t_1 \\ e_1\text{: } \boxed{x \text{ rally } y} \\ \hline \end{array}$$

Figure 1: SDRS for (2.i)

$$\pi_4: \begin{array}{|l|} \hline s_4\ t_4\ x \\ \hline t_4 < n \\ s_4 \circ t_4 \\ s_4 \circ srp(\pi_4) \\ s_4\text{: } \boxed{x \text{ PROG(tremble)}} \\ \hline \end{array}$$

Figure 2: SDRS for (2.iv), underspecified

(5) If $limit(temporal\_adv(\alpha))$, then $rp(\alpha) = temporal\_adv(\alpha)$;
Otherwise, if $event(me(\alpha))$, then $rp(\alpha) = me(\alpha)$.

If the DRS is a sentence with a temporal adverbial which limits the accomplishment of an event, the value of the function is the meaning of the temporal adverbial. Otherwise, if the relevant SDRS represents an event, its value is identified with the main event in it. In this case, $r_1 = rp(\pi_1) = e_1$ and $r_2 = rp(\pi_2) = e_2$.

When *natural_sequence* holds between two RP's, they stand in an earlier/later relationship separated by an interval of some length which is possibly null and is compliant with the world knowledge (this is glossed as $r_1 \preceq r_2$). A&L take an entirely different approach: they constrain the relationship between the poststate of the first event and the prestate of the second to overlap. However, we don't follow them, owing to the difficulty in defining pre/poststates.

DR's are classified into three groups: subordination, in which one proposition adds descriptions to the other (e.g., *Elaboration*), coordination, i.e., text developmemt as succession of events (e.g., *Narration*), and the other group (e.g., *Parallel*).

The semantics of sentence (2.iii) is given in exactly the same manner as for (2.i) and (2.ii), with (2.ii) and (2.iii) related by *Narration*. Furthermore, $r_2 \preceq r_3$.

Next, the analysis of sentence (2.iv) produces the underspecified SDRS in Figure 2. The function *s(ister-)r(eference-)p(oint)* supplies the RP of the SDRS existing, not necessarily last, in the context which is combined by a DR with the SDRS it takes. The second and third from last lines in Figure 2 are by default shared by all the stative predicates, including the continuous usage of the *te iru* form of verb.

Following K&R's analysis of the progressive, we assume the SDRS condition for the continuous predicate. s_4 stands for the state of the speaker's being trembling.

π_4 is connected to π_3 by the DR *Background* (i.e., $Background(\pi_3, \pi_4)$). Because of its behavior in terms of anaphoric reference and tense interpretation, it is treated as a kind of subordination, avoiding complicated manipulations to include it in coordinating relations as practiced by A&L.

The rule (6) applies to two SDRS's for which a subordinating relation holds. At the stage of having analyzed sentence (2.iv), the SDRS π_4 remains underspecified with the value of $srp(\pi_4)$ being undetermined. (6) equates it with the RP of π_3 ($rp(\pi_3) = srp(\pi_4) \circ s_4$). Furthermore, $rp(\pi_3) = r_3$. Note that the relevant value is fully specified in Figure 3, the result of resolution embedded within the SDRS for the whole text. The relationship between the state and the RP is specified with overlapping ($\circ$), which is a relation with wider coverage. Since $r_3 = e_3$ is not an interval, $r_3 \subseteq s_4$ is inferred from $s_4 \circ r_3$.

(6) $\phi_{Subordination(\alpha,\beta)} \Rightarrow srp(\beta) = rp(\alpha)$

This works even when the subordinate proposition β occurs before α.

The whole SDRS for text (2) explicitly represents the relationships between RP's as $r_1 \preceq r_2 \preceq r_3$, additionally with the specification $s_4 \circ r_3$ in the embedded SDRS π_4 (see Figure

$$\pi_4 : \begin{array}{|l|} \hline s_4\ t_4\ x \\ \hline t_4 < \mathrm{n} \\ s_4 \circ t_4 \\ s_4 \circ r_3 \\ s_4\text{: } \boxed{x \text{ PROG(tremble)}} \\ \hline \end{array}$$

Figure 3: SDRS for (2.iv), specified

$$\pi : \begin{array}{|l|} \hline e\ s\ t\ x\ y \\ \hline t = n \\ e \subseteq t \\ e \supset\!\subset s \\ s \circ r_0 \\ e\text{: } \boxed{x \text{ write } y} \\ \hline \end{array}$$

Figure 4: SDR for (5.ii)

3). Thus the addition of RP's as discourse referents, which L&A and A&L lack, represents the temporal development of texts in an intuitively comprehensible manner.

Our formalization has captured a parallelism between tense/aspect and reference by NP's (Partee 1973) in that an event introduces into the context a new RP, which provides a basis for understanding states including those denoted by *te iru* clauses. Specifically, both the stative aspect and anaphora remain underspecified when a single sentence has been analyzed, needing information from the context. On the other hand, a difference has been made clear. Reference by anaphora is essentially ambiguous since its antecedent needs to be chosen from among multiple candidates. By contrast, the RP is exceptionlessly identified with that of the constituent with which the stative sentence is connected by a DR, without a need for ambiguity resolution, once the connection has been made.

The resultative usage is analyzed similarly, except that the main predicate is RESULT which outputs the result state caused by the event.

5 Experiential usage of *te iru* form

The so-called EXPERIENTIAL usage of the *te iru* form indicates that an eventuality that occurred in the past exerts an indirect influence until a certain time, which is usually the utterance time. It includes cases in which none of its result but only its record remains, as in (7).

(7)

[i]Kagemichi	wa,	Ooshuu Shirakawa	de	kuma	ga	kuma	no	ko	o
NAME	TPC	PLACE	LOC	bear	NOM	bear	ADNM	child	ACC

tsure	te	tooru	no	o	mikake	ta.	[ii]Sokode	nikki	ni	'Kodomo	ni
accompany	PTCL	pass	NML	ACC	see	PST	then	diary	LOC	child	DAT

hitome	mi	se	tai'	to	**shirushi**	**te**	**iru**.
a look	see	CAUS	DESID	QUOT	write	PTCL	EXPR

'At Shirakawa in Ooshuu, Kagemichi saw a bear walking on the street with its cubs. He wrote in his diary that he wanted to let his son have a look at them.'

This type of *te iru*-sentence like (7.ii) has a noticeable feature of being combined by a DR *Narration* with another clause. Thus we need to treat it as an event, while assigning it other pieces of information typical with the *te iru* form, including assignment of an RP.

Figure 4 is an SDRS for this sentence, which is analyzed as an event and therefore can be combined with *Narration*. Simultaneously, a state s is specified in such a way that it starts when e ends (only the temporal relation is shown) and overlaps with an RP r_0. All these are introduced by the lexical description for this usage of *te iru*. r_0 is identified with an RP at the global level, the utterance time in this case. Note that an RP is indispensable to clarify the distinction from sentences without *te iru* marking, which is neutral in terms of a point of view.

.56 RP's in complex text structures

The studies on interpretation of tense and aspect in texts (K&R, L&A, and A&L) have so far been limited to cases with relatively simple text structures. It is yet to be seen if the RP defined above can be applied as it is to real texts or its essential revisions are needed. In this section, we investigate how we should modify it for one of typical texts with complexity, where a constituent which elaborates a preceding sentence is a complex one made up of sentences with a *Narration* relation.

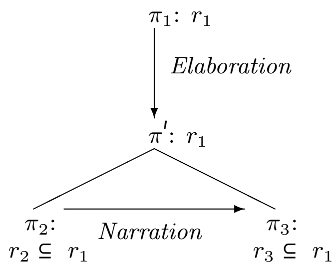

Figure 5: Discourse relations in (8)

(8) π_1: Taroo wa tanoshii nichiyoobi o sugoshi ta.
NAME TPC happy Sunday ACC spend PST
'Taroo spent a happy Sunday.'

π_2: Asa wa kooen o sampo-shi ta.
morning TPC park PATH walk-LV PST
'In the morning, he walked in the park.'

π_3: Sorekara, gaaruhurendo to eiga o mi ni it ta.
then girlfriend with movie ACC see GOAL go PST
'Then he went to see a movie with his girlfriend.'

In this text, sentences π_2 and π_3, which elaborate π_1, share the time of spending a happy Sunday with the first sentence. However, they don't inherit its RP as it is; rather, it is *split* into two parts, one of which precedes the other. To cope with such cases, we need to revise the rule (4$'$) so that the two consecutive sentences (π_2 and π_3 in (8)) may each share only a part of the RP of the constituent they elaborate (π_1 in (8)). See Figure 5.

(4$'$) $\phi_{Narration(\alpha,\beta,\lambda)} \Rightarrow natural\_sequence(rp(\alpha), rp(\beta)) \wedge rp(\alpha) \subseteq rp(\lambda) \wedge rp(\beta) \subseteq rp(\lambda)$

The RP is by default an instant, but it is compatible with being a temporal interval.

7 Conclusion

Evidenced by temporal adverbials, lexical items, and *te iru*'s requirement for RP's, we have situated RP's as discourse referents and proposed a framework based on SDRT to explain the behavior of *te iru*-marked and non-*te iru*-marked sentences. This has made clearer and more formal the intuitive observation that tense and aspect are like anaphora. We have also proposed a way to apply the concept of RP to real complex texts.

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[ABSTRACT]

Left-branching tree in CCG with D combinator*

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The essence of incremental parsing is to construct a partial syntactic structure stepwise from the head of a sentence. This parsing algorithm is especially preferable when we analyze the process for us to listen to/ read a sentence in the temporal order, and is beneficial to reveal an intermediate state of natural language understanding and to parse a long natural language sentence.

Some may argue that we possess a short term memory and can look ahead multiple words at a time prior to compose a tree structure, and thus, our parsing process may not be incremental. However, even though we can pool a few number of words as a chunk, such chunks must be processed incrementally since these chunks could hardly be pooled again unless there is a secondary short-term memory. In addition, Chomskian syntactic theory may generate an arbitrarily long sentence though generative rules are finite, and thus, we cannot predefine a ceiling of memory size. Therefore, we consider a word as the minimal chunk for the base case, and implement the word-by-word process. For example, the human chops Sentence (1) into chunks: 'High above the city,' 'on a tall column,' 'stood a statue,' and 'of the Happy Prince.' For every chunk processed by the reader, they could understand the meaning of the sentence incrementally.

(1) High above the city, on a tall column, stood a statue of the Happy Prince. [1]

In categorial grammar (CG) and its variants, there are incremental parsing algorithms [1, 2, 3], but not all grammatical sentences could be parsed by these algorithms. It is empirically known that all the grammatical sentences is parsed

*This work was supported by the JSPS KAKENHI Grant Number 22H00597 and and the Grant-in-Aid for JSPS Fellows Number 21J15207.

[1]Oscar Wilde, The Happy Prince and Other Tales, 1888.

incrementally by CG with combinator rules. As the previous researches were software simulations of the incremental parsing, we could not obtain that those algorithms work on a sentence of any length. Thus far, we have empirically shown that any grammatical sentences could be incrementally parsed [4], but no proofs to this is known to us.

A naïve structure generated of incremental parsing is a left branching tree, which has binary nodes only on the left branches. We obtain the incremental parsing by our transformation from a given arbitrary tree to the left-branching tree.

First, we define CG and its variants. CG is proof system A consists of three axiom schemata with a cut rule, where the lower letters are arbitrary any category of CG and the capital Greek letters are sequences of categories.

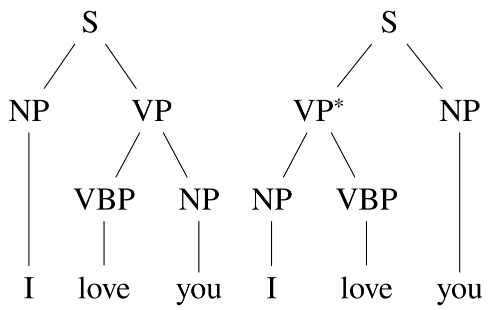

Figure 1: Non-incremental parsing (left) and Incremental parsing (right)

$$\frac{}{x \vdash x}\textsc{Id} \qquad \frac{}{x/y, y \vdash x}\mathsf{A>} \qquad \frac{}{x, x\backslash y \vdash y}\mathsf{A<} \qquad \frac{\Gamma \vdash x \quad \Sigma, x, \Delta \vdash y}{\Sigma, \Gamma, \Delta \vdash y}\textsc{Cut}$$

For example, (I) "I love you" is parsed as $np, (np\backslash s)/np, np \vdash s$ with the following derivation.

$$\frac{\dfrac{}{(np\backslash s)/np, np \vdash np\backslash s}\mathsf{A>} \qquad \dfrac{}{np, np\backslash s \vdash s}\mathsf{A<}}{np, (np\backslash s)/np, np \vdash s}\textsc{Cut}$$

According to the proof net's convention, we use a graph. The axiom schemata A>, A< are represented by the graphs in Figure 2, and the cut rule is denoted as the connection of the two graphs. Then, the graph of the above example is represented

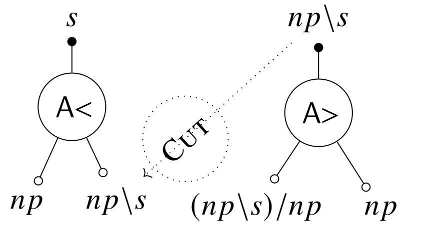

Figure 2: Graph of $A <$ and $A >$

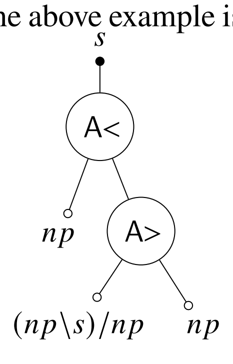

Figure 3: Graph of (I)

as the graph in Figure 3. For the sake of convenience, we employ a new notation of graphs; the graph in Figure 2 is $\mathsf{A}\!<[np, np\backslash s]_s$ and $\mathsf{A}\!>[(np\backslash s)/np, np]_{np\backslash s}$. We use the binary operator $\odot$ as adjoining tree by CUT. Then, the graph in Figure 3 is the following expression.

$$\mathsf{A}\!>[(np\backslash s)/np, np]_{np\backslash s} \odot \mathsf{A}\!<[np, np\backslash s]_s = \mathsf{A}\!>[np, \mathsf{A}\!<[(np\backslash s)/np, np]_{np\backslash s}]_s$$

Generally, only the following eight patterns are possible for each triplet of nodes, where capital Roman letters are expressions with the root category denoted as the subscript. Especially, we call the patterns (7) and (8) the *backward long reference*. In these patterns, the third category includes a hidden category for the first category, *e.g.*, The category z in the pattern (7) is appeared in the left-most/ right-most nodes as a part of functional categories. For example, post-posited adverbs 'only', in linguistics, is corresponding to this reference, which are grammatical rules but are not preferable in the conversation.

(1)	$\mathsf{A}\!>[\mathsf{A}\!>[X_{(x/z)/y}, Y_y], Z_z]_x$	(5)	$\mathsf{A}\!>[X_{x/y}, \mathsf{A}\!>[Y_{y/z}, Z_z]]_x$
(2)	$\mathsf{A}\!>[\mathsf{A}\!<[X_x, Y_{x\backslash(y/z)}], Z_z]_y$	(6)	$\mathsf{A}\!<[X_x, \mathsf{A}\!>[Y_{(x\backslash z)/y}, Z_y]]_z$
(3)	$\mathsf{A}\!<[\mathsf{A}\!>[X_{x/y}, Y_y], Z_{x\backslash z}]_z$	(7)	$\mathsf{A}\!>[X_{x/z}, \mathsf{A}\!<[Y_y, Z_{y\backslash z}]]_x$
(4)	$\mathsf{A}\!<[\mathsf{A}\!<[X_x, Y_{x\backslash y}], Z_{y\backslash z}]_z$	(8)	$\mathsf{A}\!<[X_x, \mathsf{A}\!<[Y_z, Z_{z\backslash(x\backslash y)}]]_y$

In the system A, (I) is not parsed incrementally because there is a binary node on the right branch in Figure 3. Hence, we employ a new proof system $ABTD^*$, which parses (I) without binary nodes on the right branch. Note that the system allows the cut rule only on the left-most category. Therefore, it is exactly corresponding to the left-branching tree that has not binary nodes on the right branches. Hereafter, we use the binary operator $\circledast$ corresponding to CUT*.

$$\frac{}{x \vdash^* x}\,\textsc{Id} \qquad \frac{}{x/y, y \vdash^* x}\,\mathsf{A}\!> \qquad \frac{}{x, x\backslash y \vdash^* y}\,\mathsf{A}\!< \qquad \frac{}{x/y, y/z \vdash^* x/z}\,\mathsf{B}\!>$$

$$\frac{}{x/y \vdash^* (x/z)/(y/z)}\,\mathsf{D}\!> \qquad \frac{}{x \vdash^* y/(x\backslash y)}\,\mathsf{T}\!< \qquad \frac{\Gamma \vdash^* x \qquad x, \Delta \vdash^* y}{\Gamma, \Delta \vdash^* y}\,\textsc{Cut}^*$$

In this paper, we show the main theorem; For a certain parsing tree generated by CG, we can generate the equivalent parsing tree without binary nodes on the right branch by the combinator rules B, D, T, where the condition is that there are no the backward long references (7) and (8) on the above eight patterns.

Theorem. *If* $\Gamma \vdash a$ *is derived by a tree without the backward long reference, then* $\Gamma \vdash^* a$*, which is derived by a left-branching tree.*

Proof. We use $\mathbb{1}$ and $\mathbb{2}$ to denote applicable single/ binary axiomata. To declare the correspondence, we attach the subscript to these symbols if they are needed. We prove this theorem by the mathematical induction with respect to the number of leaves. If the tree has less than three leaves, it is obviously the left-branching tree. We define the transformation $\triangleright$ of the tree. The following is the inductive definition, that is, we need to process the transformation on the upside to process ones on the downside. Let the capital Roman letters be parsing trees of CG.

$$\frac{}{x \triangleright x}\,\mathrm{I} \qquad \frac{}{\mathbb{2}[x, y] \triangleright \mathbb{2}[x, y]}\,\mathrm{B} \qquad \frac{\mathbb{2}_1[X, Y] \triangleright A_a \qquad \mathbb{2}_2[a, Z] \triangleright B}{\mathbb{2}_2[\mathbb{2}_1[X, Y], Z] \triangleright A \circledast B}\,\mathrm{E} \qquad \frac{X \triangleright A}{\mathbb{1}[X] \triangleright A \circledast \mathbb{1}[x]}\,\mathrm{U}$$

$$\frac{\mathsf{B}{>}\,[X, \mathsf{T}{<}\,[Y]] \triangleright A_a \qquad \mathsf{A}{>}\,[a, Z] \triangleright B}{\mathsf{A}{>}\,[X, \mathsf{A}{>}\,[Y, Z]] \triangleright A \circledast B}\,1 \qquad \frac{\mathbb{2}[X, Y] \triangleright A_a \qquad \mathsf{B}{>}\,[a, \mathsf{T}{<}\,[Z]] \triangleright B}{\mathsf{B}{>}\,[\mathbb{2}[X, Y], \mathsf{T}{<}\,[Z]] \triangleright A \circledast B}\,1\mathrm{L}$$

$$\frac{\mathsf{D}{>}\,[X] \triangleright A_a \qquad \mathsf{A}{>}\,[a, \mathsf{A}{>}\,[Y, Z]] \triangleright B}{\mathsf{B}{>}\,[X, \mathsf{T}{<}\,[\mathsf{A}{>}\,[Y, Z]]] \triangleright A \circledast B}\,1\mathrm{R} \qquad \frac{\mathsf{T}{<}\,[X] \triangleright A_a \qquad \mathsf{A}{>}\,[a, \mathsf{A}{>}\,[Y, Z]] \triangleright B}{\mathsf{A}{<}\,[X, \mathsf{A}{>}\,[Y, Z]] \triangleright A \circledast B}\,5$$

Here, we show the following two properties of the transformation $\triangleright$.

(i) The transformation works for any tree without the backward long reference.
(ii) The transformation terminate and we obtain the left-branching tree.

First, we prove (i) with respect to the outermost form of the tree.

- If the tree is just a category, then it is transformed by I.
- If the tree has only two leaves, then it is transformed by B.
- If the outermost form of the tree is the pattern (1), (2), (3), and (4), then it is transformed by E. Following that, as $\mathbb{2}_1[X, Y]$ and $\mathbb{2}_2[a, Z]$ are the trees of less than n leaves in CG, it can be transformed by $\triangleright$.
- Note that category a in all the transformations appears at the top-most in a tree. This means that the category a remains unchanged by the transformation because there are no more applicable transformation rules to a.
- If the outermost form of the tree is the unary rule, then it is transformed by U. As the tree X is also the tree in CG, it can be transformed to A inductively.
- If the outermost form of the tree is the pattern (5), then it is transformed by 1. There are no backward long reference in the tree by the assumption.
  - For $\mathsf{A}{>}\,[a, Z]$, there are two cases: Z is a leaf or $\mathsf{A}{>}\,[\ldots]$. If it is a leaf, then it is transformed by B. Otherwise, as it is a tree of less than n leaves in CG, it is inductively transformed by $\triangleright$.
  - For $\mathsf{B}{>}\,[X, \mathsf{T}{<}\,[Y]]$, it is not a tree in CG because of $\mathsf{B}{>}$and $\mathsf{T}{<}$. Thus, we must define the transformation for each situation. If the outermost form of X is $\mathbb{2}[\ldots]$, then it is transformed by 1L. If the outermost form of Y is $\mathbb{2}[\ldots]$, then it is transformed by 1R.
- If the outermost form of the tree is $\mathsf{B}{>}\,[\mathbb{2}[X, Y], \mathsf{T}{<}\,[Z]]$, then it is transformed by 1L. $\mathbb{2}[X, Y]$ is inductively transformed by $\triangleright$ because it is the tree of less than n leaves in CG. $\mathsf{B}{>}\,[a, \mathsf{T}{<}\,[Z]]$ is transformed by 1R.

- If the outermost form of the tree is $\mathsf{B}>[X,\mathsf{T}<[\mathsf{A}>[Y,Z]]]$, then it is transformed by 1R. $\mathsf{D}>[X]$ is transformed by U. $\mathsf{A}>[a,\mathsf{A}>[Y,Z]]$ is transformed inductively because the tree has less than n leaves.
- If the outermost form of the tree is the pattern (6), it is reduced into the pattern (5) by the transformation rule 5. $\mathsf{T}<[X]$ is transformed by U. $\mathsf{A}>[a,\mathsf{A}>[Y,Z]]$ is transformed by (5).
- There are no other outermost form because of the assumption of the theorem.

Next, we prove (ii) for the transformation $\triangleright$. For each transformation, we adjoin the transformed subtree by $\circledast$ to adjoin the left-branching trees without any right-branching. Thus, the transformation generates left-branching tree only. Moreover, For each transformation step, the depth of tree and number of leaves of subtree is decreasing. Since the number of leaves and the depth of tree is finite, the transformation should terminate in finite steps. If we have $\Gamma \vdash a$ holding the assumption, then there is a tree X, and we obtain a certain Y by $X \triangleright Y$. Y is a graph representation of the proof in $ABTD^*$. Thus, we obtain the proof of $\Gamma \vdash^* a$. $\square$

We have shown the efficient transformation from a given syntactic tree to a left-branching one regarding the pattern (1) – (6), though we excluded those sentences with the backward long reference. The naïve implementation [4] of incremental parser produces the backtracking many times. As a consequence, the complexity of incremental parser to obtain the left branching tree is exponential, though a non-incremental parser, in general, $O(n^k)$. However, we could obtain a transforming algorithm with $O(n)$, and thus, the parsing complexity to obtain the left-branching tree is the same as $O(n^k)$ because $O(n^k) + O(n) = O(n^k)$.

We have not dealt with the backward long reference. Empirically, we see the tree for such a reference by the Q combinator rules. However, the left branching tree is drastically changed and several variations from the original trees. Hence, we remain the transformation for these patterns as future work.

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To be Canceled, or Not to be Canceled: Reconsidering the Caused Possession in the Dative Alternation Experimentally

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1 Reviewing Literature on the Dative Alternation

The alternation between the prepositional dative construction (PDC) in (1a) and the double object construction (DOC) in (1b) (i.e. the dative alternation) has a long history of research in the generative tenet, and there should be at least two headings of the pertinent research: (i) they are derived from the same structure, setting aside the issue concerning which of (1a) or (1b) is the base, or (ii) they are not derivationally intertwined, each endowed with different syntactic makeups, i.e. what Harley (2002) terms the "alternative projection" view.

(1) a. John gave a ring to Mary. (PDC)
    b. John gave Mary a ring. (DOC)

Those who advocate the alternative projection approach sometimes observe that DOC, not PDC, is accompanied by the entailment that the goal has got the theme because of the agent's giving/passing/sending/throwing etc. event. However, the facts are, as pointed out by Rappaport Hovav and Levin (2008) among others, not so simple, and they observe that verbs like *give*, *lend*, *loan* and *sell* (GIVE-type verbs) do not allow the cancellation of caused possession, irrespective of the DOC or PDC frame whereas other verbs like *send* are compatible with such a cancelled interpretation:

(2) a. #My aunt {gave/lent/loaned} my brother some money for new skis, but he never got it.
    b. #My aunt {gave/lent/loaned} some money to my brother for new skis, but he never got it.

(3) a. #My brother sold Caroline his old car, but she never owned it.
    b. #My brother sold his old car to Caroline, but she never owned it.

(4) a. Lewis sent Sam a bicycle, but it never arrived.
    b. Lewis sent a bicycle to Sam, but it never arrived. (Rappaport Hovav and Levin 2008: 146-147)

This state of affairs then rejects a uniform analysis of DOC with the caused possession lexicalized as HAVE in the DOC structure (Beck and Johnson 2004, Harley 2002 inter alia). If HAVE lexicalizes the caused possession, we need it even in the PDC frame, and it should be absent in (4) in both frames.

Also, Basilico (2008) observes that inanimate subjects force the DOC frame to be accompanied by the caused possession construal, even for non-GIVE-type verbs:

(5) Those heavy April showers brought us some nice May flowers (#but we didn't get nice flowers this May). (Basilico 2008, 760)

Proposing any specific structures building on the set of data collected from only a handful of speakers may jeopardize the reliability of the analysis, so we conducted a survey regarding the cancelled possession, finding out that even *give* and other GIVE-type verbs are possible with it (if the subject is animate).

2 Method and Result

In an attempt to empirically test the above point in an experiment, the research hypothesis is as follows. The dative alternation presupposes that both DOC and PDC sentences containing the same verb are acceptable. On this premise, when a sentence containing cancellation follows them, only DOC becomes unacceptable, which proves the existence of HAVE in the syntactic structure only in DOC. On the other hand, if only GIVE-type verbs are affected by cancellation and no difference is found between DO and PO, then the above-discussed explanation by Rappaport Hovav and Levin (2008) is supported. We confirmed through Experiment 1 with 100 American native speakers of English whether both DOC and PDC stimuli used in this experiment are acceptable as Figure 1 shows, and through Experiment 2 with another 100 American native speakers of English how the acceptability changes when a cancellation follows the sentence used in Experiment 1. Bayes factor (BF_{10}) and Bayesian 95% credible intervals were used to assess whether the participants tended to judge each stimulus as grammatical or ungrammatical. The results (Figure 2) showed that acceptability declined when stimuli accompany the cancellation of the caused possession as an overall tendency, but DOC and PDC showed almost the same trends as Rappaport Hovav and Levin (2008) have shown. Interestingly, the acceptability of *give* and *loan* declined when followed by cancellation, but it did not decline to the point of being judged completely ungrammatical, contra what Rappaport Hovav and Levin observe, and we found that *show*, *sell*, *lend* were judged as ungrammatical when followed by cancellation, although there was not much difference between DOC and PDC.

Figure 1: Without Cancellation

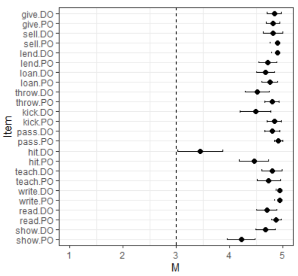
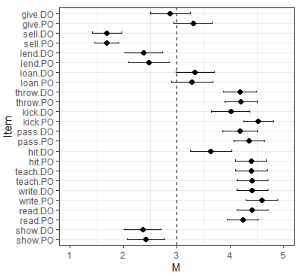
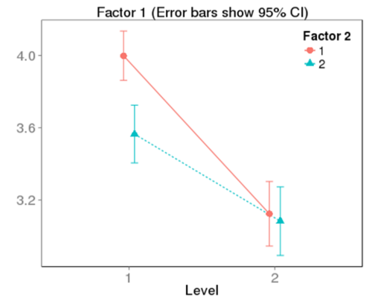


Figure 2: With Cancellation



We also conducted two more judgment experiments: Experiment 3 tested the acceptability of the inanimate subject of DOC and PDC sentences, and Experiment 4 investigated the change of these sentences when cancellation was added to these sentences. One hundred American native speakers of English were recruited for each experiment and engaged in the acceptability judgment task. The data obtained analyzed in the same manner as Experiment 1 and 2. The results showed that DOC showed a significantly higher acceptance rate than PDC without cancellation, while neither condition became completely unacceptable. When cancellation is added, however, both showed significantly lower acceptance rates and there is not significant difference between DOC and PDC as the following figure shows:

Figure 3: Inanimate Subject with/without Cancellation



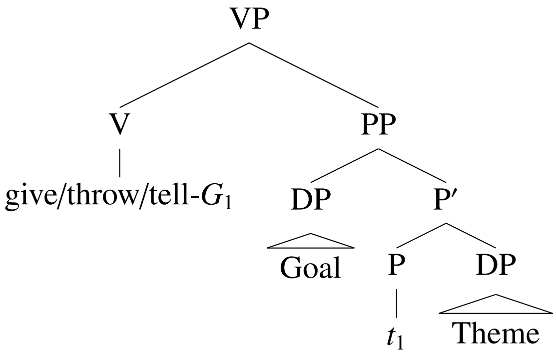
Factor 1: level 1 = without cancellation, level 2 = with cancellation
Factor 2: 1 = DOC, 2 = PDC

What is interesting about Figure 3 is that inanimate subjects are possible even for the PDC frame, and this state of affairs is contrary to what Lechner (2006) and Pesetsky (1995) point out, whereas supporting Basilico's (2008) observation that the caused possession is obligatory for the inanimate subject DOC.

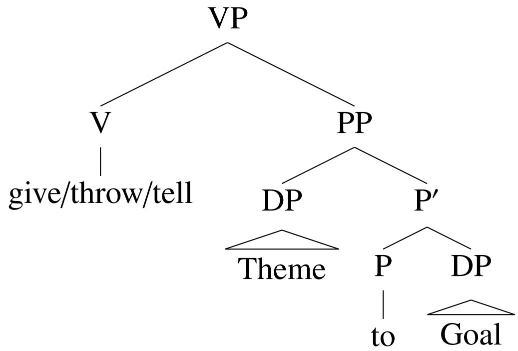
3 The Syntax of the Dative Alternation

The results of our survey indicate that postulating HAVE for even GIVE-type verbs is not well motivated, and importantly, they show that the obligation of the caused possession interpretation does not concern the dative alternation itself but more intricate factors such as the meaning of individual verbs and the animacy of their subject. We thus do not assume HAVE, and following Pesetsky (1995), we argue that both DOC and PDC involve PP, and that only the former has a silent preposition, viz. Pesetsky's *G*. Under his analysis, it incorporates to V, so we have:

(6) a. Double Object Construction



b. Prepositional Dative Construction



Note that in both frames there is not direct selectional relation between the verb and the two arguments. This is supported by (7), which shows that omitting a goal argument (in an out-of blue context) leads to ungrammaticality.

(7) a. *John gave a book.

b. ?*John sent a letter. (Takami 2003: 219)

Then, immediate questions should be concerned with how the complex facts exhibited by the above results can be captured as well as what motivates the dative alternation. Regarding these issues, we however do not ask syntax for the answers; instead, we try to incorporate ideas put forth by cognitive grammar to our analysis.

4 Explaining The Dative Alternation – Where Cognitive Linguistics and Generative Grammar Meet

We contend that the dative alternation should be understood in terms of cognitive and pragmatic factors such as salience, attention shift, and information structure. Langacker (2008) argues that when a verb profiles three participants (agent, mover, receiver), the agent is focused as the trajector because it is the most prominent, followed by the object adjacent to the verb as the first landmark. Thus, to express the event of transfer, English speakers have the option of either PDC where the mover is focused as the (first) landmark, or DOC where the recipient is focused instead. The length of the noun phrase, (in)definitness, (in)animacy, and other discourse-related variables are also related to these factors and affect choice of these constructions (Bresnan et al. 2007). The focus of the event is then determined by factors such as how the language speaker conceptualizes the content of consciousness and what kind of linguistic expression the context requires. We also argue that whether a given verb tends to (or must) be accompanied by the caused possession construal depends on to what extent such an interpretation is conventionalized for the verb and/or what kind of situation a given language speaker is facing.

Concerning the inanimate subject in the dative alternation, Ikegami (1981) proposes an figure-ground alternation between *action* and *result* in the construal of the meaning expressed by the sentence, and argued that inanimate subjects are more acceptable when action by an inanimate subject is not in the foreground (Ikegami 1981). As Goldberg (1995) also shows that volitionality is diminished in the inanimate subject construction, this could increase the acceptability of DOC over PDC for inanimate subjects. In addition, since inanimate subjects draw interpreters' attention on result rather than action, inanimate subjects are likely to be less compatible with cancellation of the result than when animate subjects are positioned. This could reduce the acceptability of the sentences, regardless of the types of construction.

The above kinds of cognitive/pragmatic processes are done after constructing a structure in narrow syntax, namely after Spell-Out. Therefore, it can be considered that they consult the conventionalized/encyclopedic knowledge of each language user. This does not necessarily contradict what the current generative approach assumes. Under the framework of Distributed Morphology (DM), word formation is done in narrow syntax, and all the interpretational processes are rendered after Spell-Out, and DM also assumes the encyclopedic knowledge of the language user, and in this connection, Lohndal (2014) claims that the argument structure, a case of non-word level interpretation, may also consult speakers' conventionalized/encyclopedic knowledge. However, what kinds of determinants are significant in the relevant processes are, if not all of them, yet to be known. If syntax is only for recursion, cognitive linguistics and generative grammar can help each other move forward to a better understanding of human language, especially what will actually happen after narrow syntax – the language faculty in the broad sense (Hauser et al. 2002).

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Events and Relative Clauses

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Abstract. This work is the continuation of the development of polynomial event semantics (a dialect of Neo-Davidsonian event semantics), using the FraCaS textual entailment corpus as a whetstone. This time we grapple with various, often complicated, relative clauses.
Relative clauses have hardly been analyzed before in event semantics. Although simple cases are straightforward, challenges arise when a clause contains quantification, coordination or negation. We deal with such complications in the present paper, focusing on entailments.

This work is the continuation of [3–5] on polynomial event semantics and textual entailment.

Deciding entailments 'by pure logic', without resorting to meaning postulates is one of the most attractive features of event semantics. However, beyond the classical "Brutus stabbed Caesar violently", one quickly runs into problems. One is quantification, described and dealt with in [3, 5]; another is negation [4]. There are also relative clauses, which are rarely considered in event semantics. In fact, the recent survey [7] and the extensive study [1] give, among the multitude of examples, not a single analysis of a sentence with a relative clause.

A relative clause appears already in the very first problem in the FraCaS textual inference problem set [2, 6]:

(1) There was an Italian who became the world's greatest tenor.

Such simple case was analyzed in [5]. But even a slightly more complicated problem 018 below requires quite a non-trivial entailment reasoning involving the relative clause.

(2) Every European has the right to live in Europe.
(3) Every European is a person.
(4) Every person who has the right to live in Europe
can travel freely within Europe.
(5) Every European can travel freely within Europe.

As in all FraCaS problems, the goal is to determine the entailment of the last sentence (in our case, (5)) from the others. We must stress that FraCaS collects not only positive examples of expected entailments, but also negative examples where entailment does not hold – and also "yes and no" cases where entailment comes through only on some readings. Our goal is hence not only to derive entailments where expected, but also to explain why entailment does not hold in negative examples, as well as to reproduce several readings where present.

FraCaS has quite a few problems similar to the above, with copula relative clauses (problems 005, 006, 028) and quantifiers like 'most' (problem 074). Object relative clauses also appear (e.g., problems 133 and 344). There are further complications, with quantified or coordinated relative clauses:

(6) There was one auditor who signed all the reports.
(7) There is a car that John and Bill own.
(8) There is a representative that Smith wrote to every week.

The following NPs, although not appearing in FraCaS, are also common:

(9) two students who skipped three classes
(10) every student who skipped no classes
(11) a student who didn't skip all classes

The present paper gives analysis of all such sentences and NPs, focusing on entailments. Due to the lack of space in this extended abstract, many details are elided.

1 Background

First a brief reminder of polynomial event semantics. It deals with events, notated e, such as 'having become the world's greatest tenor' or 'being Italian' or 'having the right to live in Europe' (we denote the latter set of events as RtlE). It should be clear that we take events in broad sense (as detailed in [7]): associated not only with actions but also states. Besides events, there are also individuals, notated i, such as john, and relations between events and individuals (written as rel') such as

$$\mathsf{subj}' = \{(e,i) \mid \mathsf{ag}(e) = i\} \qquad \mathsf{ob1}' = \{(e,i) \mid \mathsf{th}(e) = i\}$$

where ag and th are thematic functions (for agents and themes of events, resp.).

Remark 1. The terms 'agent' and 'theme' are used purely formally. After all, event semantics is widely praised for avoiding meaning postulates and deriving entailments from the structure alone. Likewise, the focus of FraCaS is textual entailment without relying on world knowledge. We, too, concentrate on the structure: Just as verbs have arguments, events – records in a world database – have attributes. We use 'agent' and 'theme' to refer to the attributes. What actions or attributes really mean and what is their connection with agency, etc., is out of scope.

If rel' is a relation of events to individuals, $\mathsf{rel}'/\ i = \{e \mid (e,i) \in \mathsf{rel}'\}$ is the set of events related to i. In particular,

$$\mathsf{subj}'/\ \mathsf{john} = \{e \mid (e,\mathsf{john}) \in \mathsf{subj}'\} = \{e \mid \mathsf{ag}(e) = \mathsf{john}\}$$

is the set of events whose agent is john. The semantics of a simple sentence such as "John has the right to live in Europe" is given compositionally as

(12) $$\mathsf{subj}'/\ \mathsf{john} \ \cap\ \mathsf{RtlE}$$

Subject, predicate, complements all denote event sets, and the whole sentence is their intersection. In particular, our sentence denotes – or, witnessed by – events of having the right to live in Europe whose agent is John. The denotation is hence an event set –

or the formula representing it, as (12), which one may think of as a query of the record of events in the world. A sentence is true in that world just in case the result of the query is a non-empty event set.

The denotation of the subject is also determined compositionally, by applying subj' to the denotation of NP, in our case, john.

We often deal not with individuals but with sets of individuals such as $\mathsf{Student}$ or $\mathsf{European}$, which are the denotations of common nouns. Determiners pick which individuals from this set to consider. Correspondingly, they call for generalization: the introduction of (internal) choice $\sqcup$ (for narrow-scope existentials and indefinites), external choice $\oplus$ (wide-scope ones) and grouping $\otimes$. Thus $\mathsf{john} \sqcup \mathsf{bill}$ is a choice between John and Bill, whereas $\mathsf{john} \otimes \mathsf{bill}$ is a group of John and Bill: both have to be involved, not necessarily in the same action however. Likewise, event sets are generalized to *poly-concepts*, such as $d_1 \otimes d_2$ for two disjoint event sets d_1 and d_2, which specifies that an event from d_1 *and* an event from d_2 must have transpired. We define for convenience

$$\mathcal{E}c = \sqcup_{j\in c}\, j \qquad\qquad \mathcal{I}c = \oplus_{j\in c}\, j \qquad\qquad \mathcal{A}c = \otimes_{j\in c}\, j$$

The meaning of "All Europeans/Every European" is then $\mathcal{A}\ \mathsf{European}$ and "A European" (narrow scope) is $\mathcal{E}\ \mathsf{European}$. Thus (2) has as its denotation

$$(\mathsf{subj}'/\ \mathcal{A}\mathsf{European})\ \sqcap\ \mathsf{RtlE} \quad = \mathcal{A}(\mathsf{subj}'/\ \mathsf{European})\ \sqcap\ \mathsf{RtlE} \tag{13}$$

$$= \bigotimes_{i\in\mathsf{European}} (\mathsf{subj}'/\ i\ \cap\ \mathsf{RtlE}) \tag{14}$$

where $\sqcap$ is the generalization of set intersection $\cap$ to polyconcepts; $\mathsf{subj}'/$ is likewise generalized to apply to sets of individuals and poly-individuals – as homomorphism. The distribution laws detailed in [5] lead to (14), which asserts there is a group of non-empty events of having right to live in Europe, and each European is an agent of some event in that group.

2 Subject Relative Clauses

The problem is then determining the meaning of "who has the right to live in Europe." If RtlE is the set of events of having the right to live in Europe, then who has that right is the agent of these events. Thus the denotation of our subject relative clause, to be notated as $\overline{\mathsf{subj}}'/\ \mathsf{RtlE}$, is the set of individuals

$$\overline{\mathsf{subj}}'/\ \mathsf{RtlE} = \{\mathsf{ag}(e) \mid e \in \mathsf{RtlE}\} \tag{15}$$

Then (4) has as its denotation

$$\mathsf{subj}'/\ \mathcal{A}\left(\mathsf{Person} \cap (\overline{\mathsf{subj}}'/\ \mathsf{RtlE})\right)\ \sqcap\ \mathsf{CtfE} \tag{16}$$

where CtfE is the set of events of having the possibility to freely travel within Europe. This analysis is more or less what was described in [5], but recast now in simpler terms. It takes us quite far: many more FraCaS problems can be analyzed similarly.

However, relative clauses with quantifiers, coordination or negation present a problem. Again we need to generalize. Remembering the definition of the subj' relation, we may re-write (15) as

$$\begin{aligned}&\overline{\mathsf{subj}}'/\ \mathsf{RtlE} = \{\mathsf{ag}(e) \mid e \in \mathsf{RtlE}\}\\ &= \{i \mid e \in \mathsf{RtlE}\ , (i, e) \in \mathsf{subj}'\} = \{i \in \mathrm{dom}(\mathsf{subj}') \mid \mathsf{subj}'/\ i \cap \mathsf{RtlE} \neq \varnothing\}\end{aligned}$$

One may notice that $\mathsf{subj}'/\ i \cap \mathsf{RtlE}$ is exactly the meaning of "i has the right to live in Europe". Thus "who has the right to live in Europe" is the set of those i in the domain of the subj' who make the sentence true (in the world of the discourse). We may thus define the denotation of a subject relative clause as

$$\overline{\mathsf{subj}}'/\ d = \{i \in \mathrm{dom}(\mathsf{subj}') \mid \mathsf{subj}'/\ i \cap d \neq \varnothing\} \tag{17}$$

where d is the event set that is the denotation of the rest of the clause (without "who"). This is already helpful: recall (2) and its denotation (14), which says that $\mathsf{subj}'/\ i\ \cap\ \mathsf{RtlE}$ is non-empty for all $i \in \mathsf{European}$. Then (17) immediately gives $\mathsf{European} \subset \overline{\mathsf{subj}}'/\ \mathsf{RtlE}$; in words: the set of who has the right to live in Europe includes all Europeans. Likewise, (3) gives $\mathsf{European} \subset \mathsf{Person}$, leading to $\mathsf{European} \subset (\mathsf{Person} \cap \overline{\mathsf{subj}}'/\ \mathsf{RtlE})$. Then, by monotonicity of $\mathcal{A}$, (16) entails $\mathsf{subj}'/\ (\mathcal{A}\mathsf{European}) \sqcap \mathsf{CtfE}$, which is the denotation of (5). This is the solution to FraCaS 018.

Definition (17), unlike (15), now easily generalizes to the case when the denotation of the rest of the clause d is not an event set but a polyconcept with choice or grouping:

$$\overline{\mathsf{subj}}'/\ d = \{i \in \mathrm{dom}(\mathsf{subj}') \mid \mathsf{subj}'/\ i \sqcap d\ \neq \bot\} \tag{18}$$

where $\bot$ is the null polyconcept. The generalization lets us analyze quantified and coordinated relative clauses such as (6)-(8).

Let us first notice that $\overline{\mathsf{subj}}'$ is sort of an inverse of subj': we have $\overline{\mathsf{subj}}'/\ \mathsf{subj}'/\ i = \{i\}$ for any individual i. Further, $\overline{\mathsf{subj}}'/\ \mathsf{subj}'/\ \mathcal{E}S = S$ for any sets of individuals S (and the same for $\mathcal{I}$). However, unlike subj', $\overline{\mathsf{subj}}'$ is not a homomorphism. In particular, $\overline{\mathsf{subj}}'/\ \mathsf{subj}'/\ \mathcal{A}S$ is always the empty set. More interestingly, since the external choice $\oplus$ distributes over $\sqcap$ (and any other operation for that matter), we have $\overline{\mathsf{subj}}'/\ (d_1 \oplus d_2) = \overline{\mathsf{subj}}'/\ d_1 \cup \overline{\mathsf{subj}}'/\ d_2$ and further

$$\mathsf{subj}'/\ \mathcal{I}S \sqcap d = \bigoplus_{i \in S} \mathsf{subj}'/\ i \sqcap d$$

which eventually leads to

$$S \cap \overline{\mathsf{subj}}'/\ d = \overline{\mathsf{subj}}'/\ (\mathsf{subj}'/\ \mathcal{I}S \sqcap d) \tag{19}$$

or, in concrete terms,

$$\mathsf{Person} \cap \overline{\mathsf{subj}}'/\ \mathsf{RtlE} = \overline{\mathsf{subj}}'/\ (\mathsf{subj}'/\ \mathcal{I}\mathsf{Person} \sqcap \mathsf{RtlE})$$

The formula in the parentheses is the denotation of "A person has the right to live in Europe.". The role of $\overline{\mathsf{subj}}'$ then is collecting such persons into a set.

Hence (4) will have as its denotation

$$\mathcal{A}\ \mathsf{subj}'/\ \overline{\mathsf{subj}}'/\ (\mathsf{subj}'/\ \mathcal{I}\mathsf{Person} \sqcap \mathsf{RtlE})\ \ \sqcap\ \ \mathsf{CtfE}$$

which may be regarded as a database join, of "A person has the right to live in Europe." with "can travel freely within Europe" on agent. Such database join may be illustrated by a (bit contrived) paraphrase: "Some people have the right to live in Europe. Every one of them can travel freely within Europe." Generalizing, a more complicated "This sport trains muscles you never thought existed." can hence be paraphrased as "You never thought some muscles existed. This sport trains them."

More interesting is the application to quantified relative clauses, such as (6), whose denotation is

$$\mathsf{subj}'/\ \mathcal{E}\ \Big(\mathsf{Auditor} \cap \overline{\mathsf{subj}}'/\ (\mathsf{Sign} \sqcap \mathsf{ob1}'/\ \mathcal{A}\mathsf{Report})\Big) \sqcap \mathcal{E}\ \mathsf{Be}$$

where $\mathcal{E}\mathsf{Be}$ is an existence event (see [5]). This denotation is equivalent[1] to

$$\mathsf{Auditor} \cap \overline{\mathsf{subj}}'/\ (\mathsf{Sign} \sqcap \mathsf{ob1}'/\ \mathcal{A}\mathsf{Report})$$

which, by (19), is

$$\overline{\mathsf{subj}}'/\ (\mathsf{subj}'/\ \mathcal{I}\mathsf{Auditor} \sqcap \mathsf{Sign} \sqcap \mathsf{ob1}'/\ \mathcal{A}\mathsf{Report})$$

and, in turn, is equivalent to $\mathsf{subj}'/\ \mathcal{I}\mathsf{Auditor} \sqcap \mathsf{Sign} \sqcap \mathsf{ob1}'/\ \mathcal{A}\mathsf{Report}$. In other words, (6) is equivalent to, or mutually entails, "One particular auditor/the same auditor signed all the reports" – which is what FraCaS problem 196 is all about.

For object relative clauses such as (7), we use the thematic function th in place of ag, and $\mathsf{ob1}'$ instead of subj'. For example, we obtain that (7) is equivalent to "John and Bill own the same car". For problem 308, we obtain (8) is equivalent to "Smith wrote to a representative every week." on the wide-scope reading of the indefinite – with no entailment for the narrow-scope reading.

Negation calls for one more generalization of (18):

$$\overline{\mathsf{subj}}'/\ d = \{i \in \operatorname{dom}(\mathsf{subj}') \mid \operatorname{justified}(\mathsf{subj}'/\ i \sqcap d)\}$$

where justified(d) means that either d is marked as negative (as a counter-example) and is $\perp$, or not marked as negative and is not $\perp$ (see [4, 5]). We obtain that "student who didn't skip all classes" is the set $\mathsf{Student} \cap \overline{\mathsf{subj}}'/\ (\neg\ \mathsf{Skip} \sqcap \mathsf{ob1}'/\ \mathcal{A}\mathsf{Class})$, and it is the complement of the set of students who skipped all classes. Likewise, "student who skipped no classes" is the complement of the set of students who skipped a class.

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[1] We call two polyconcepts/event sets to be equivalent just in case when one is not-$\perp$/not-empty, so is the other – that is, when they entail each other.

Truthmaker Semantics for Degreeism of Vagueness

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Philosophers have been long discussed vagueness and its related paradox — the sorites — for many reasons, mostly linguistic, sometimes metaphysical, and more (cf. [5]). When philosophers talk about vagueness, they often end up talking about semantics. In fact, many solutions to the paradox suggest revising semantics: supervaluationism renovates semantics with a new formal concept of supervalues, degreeism suggests many-valued logic and its coresponding semantics, and epistemicism suggests keeping classical logic and semantics fixed, but ascribes vagueness to an epistemic issue. In the market of semantic builders, *truthmaker* is a rising star with its expressive power powerful enough for many including hyperintensionality ([3]).

Still, few have employed truthmakers for vagueness. An exceptional case [7] suggests an argument appealing to truthmaker gaps but only for his particular version of epistemicism. But might there be other applications of truthmaker semantics in the study of vagueness?

The goal of this paper is to offer an affirmative answer to this question, by designing a truthmaker semantics for another position on vagueness. Among several positions, this paper works on a popular one: *degreeism* (*degree theory*). True to its name, degreeism revises the semantic concept of a truth value from binary one (truth 1 and false 0 and nothing else) to a many-valued one (often infinite). However, importing truthmakers into degreeism is not straightforward. While truthmakers are about *quality* and use mereological part-whole relations in their formalization, degreeism is based on a more *quantitative* idea, namely a segment of real numbers $[0,1] \subseteq \mathbb{R}$. But how can we translate mereological structures of truthmaking into degreeists' real numbers and the other way around?

One option is to import *measure theory* (cf. [2], [1]). A measure is, very roughly put, a mathematical generalization of geometrical measures such as distance, length, area, and volume. This formal notion of "measuring" the size of a given set is applied to many things such as physical mass and, most importantly for degreeism, probability of events. Given that degreeism is often associated with probability theory as they both feature a fragment of real numbers $[0,1]$ as a central part of their formalization, the match already seems apt. We see an evaluation function μ which assigns a truth value for a given truthmaker as a measure function, which satisfies standard axioms of measure theory.

A glance at the definitions shows how naturally these concepts fit degreeism. For one thing, degreeism stipulates that the measure of the null set is zero

$$\mu(\emptyset) = 0.$$

This seems to correspond to our intuitive idea that if a proposition φ has no truthmaker at all (in other words, nothing in a world supports φ) its truth value should be zero. Also, another important definition of *(countable) additivity* confirms our idea of the relationship between truthmakers and truth values — the more truthmakers (e.g. evidence) a proposition has, the more likely it is that the proposition is true.

Still, measure theory is built upon a set-theoretical setting (i.e. upon families of sets), which is different from the mereological structures of truthmakers. So some formal work is needed in order to offer a mereological version of a measure function μ_{TM}. In this paper, I offer a truthmaker semantics for degreeism of the following form:

$$M = \langle S, \sqsubseteq, \mu_{TM} \rangle,$$

where S is a non-empty set of states (truthmakers), $\sqsubseteq$ is a partial order on S expressing mereological relation for part-wholehoodness, and μ_{TM} is a degreeism evaluation function from propositions to $[0,1] \subseteq \mathbb{R}$, assigning a real number from 0 to 1 to a given propositional letter. The first two suggestions follow from the standard formalism of truthmaker semantics. The last one is original. In particular, I design the following two properties for μ_{TM} so as to behave as a measure. First, we need something corresponding to the null set. In the original measure theory, we have $\emptyset$ as an obvious and natural example. But truthmakers do not have apparent counterparts of the empty set. Second, we need a truthmaker version of additivity. I provide several operations such as $\sqcap$ ($s \sqcap t$ is the overlapping part of s and t) and difference $\setminus$ of truthmakers for this purpose.

Having introduced truthmaker semantics for degreeism, this paper discusses the benefits of this semantics to further support how truthmakers are useful in discussions of vagueness, at least for degreeism. The resulting semantics resolves two formal issues for degreeism. One is about triviality [6]. Some may want to characterize vague predicates (from non-vague ones) by the formal concept of continuity. For instance, we may want to characterize vague terms by whether their evaluation function from (a subset of) $\mathbb{N}$ (e.g. the number of hairs) to truth values $[0,1]$. Unfortunately, this does not work because the domain (the number of hairs, with the most natural topology) is discrete, hence any function from $\mathbb{N}$ is trivially continuous. In my suggested framework, such a worry disappears. The domain is not the natural numbers but a set of truthmakers, whose topology is not necessarily discrete. The other is called the problem of "penumbral connection" [4]. This problem is about how to calculate the truth values of two vague clauses connected by logical connectives. For instance, what happens if two indefinite clauses (i.e. borderline cases) are connected with a conjunction, say, "This ball is purple and this ball is red"? The truth value of this sentence should be zero i.e. definitely false because one ball cannot have different colors at the same time. But typical degreeists say it is indefinite, i.e. somewhere between $[0,1]$. Truthmakers provides an easy way out, though. It is clear that a truthmaker for being red and another truthmaker for being purple are simply incompatible.

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KK is Wrong Because We Say So

Simon Goldstein and John Hawthorne

1 Against KK

The KK principle says that if you know something, then you know that you know it.

The KK principle plays a central role in theories of linguistic communication. Since at least Stalnaker 1978, many have interpreted assertion against a background of shared information, the common ground. The common ground is standardly understood in terms of iterated attitudes: what the group of interlocutors commonly accept, believe, or know. As Greco 2014 and others have argued, these common attitudes rely on some version of the KK principle. In order for a group to know that everyone knows that everyone knows that … everyone knows p, it is necessary that each member of the group knows that they know everything that they know. Otherwise, the failure of iterated knowledge (or acceptance, or belief) for individual group members will generate failures of common knowledge (or acceptance, or belief) for the group.

Unfortunately, we think KK is wrong. Moreover, KK is wrong because it is incompatible with commonplace linguistic practice. In particular, we'll argue that KK is wrong because of the linguistic practices of those who deny KK.

Doubting Dudley says that he knows he has hands, but he doesn't know that he knows … that he knows that he has hands. In logician speak, he says that he doesn't '100-know' that he has hands. (You 1-know something if you know it. You n-know something if you know that you n-1 know it.)

Dudley only says things that he believes. And he never believes things that he knows are false. Since he says he doesn't 100-know that he has hands, he believes he doesn't 100-know he has hands. So he doesn't know that he 100-knows that he has hands. But if KK is true, and if he knows he has hands, then it follows that he does know that he 100-knows that he has hands. So KK is wrong.[1]

(It may help to state the argument using the tools of epistemic logic. Let 'Ap', 'Bp', and 'Kp' represent the claims that Dudley asserts, believes, and knows p. Here is the argument: A~100Kp |= B~100Kp. B~100Kp |= ~K100Kp. So Ap & A~100Kp implies Kp & ~100Kp, which contradicts KK.)

We don't even need to say that KK is wrong. KK is wrong if we don't say that it's right. Agnostic Agnes is asked whether she 100-knows she has hands, and she refrains from answering, because she is unsure. Agnes doesn't refrain from answering questions when she knows the answer. Since she refrains from answering the question of whether she

[1]Dudley may say that KK fails without saying exactly where it fails. For example, Dudley may say the conjunction *he doesn't 100-know he has hands and he doesn't 100-know he has feet, and either he knows he has hands or he knows he has feet*. He says the conjunction, so he believes the conjunction, so he doesn't know the conjunction is false. But if KK is true, and if he does know he has hands, then he does know that the conjunction is false.

100-knows she has hands, she does not know that she 100-knows she has hands. So KK is wrong.

Here is an analogy. Agnes doesn't know exactly what love is. Is loving someone a matter of wanting their life to go well? Or do you also have to enjoy spending time with them? Agnes has a friend, Boris, who she doesn't like spending time with, but who she wishes the best for. Since Agnes doesn't know exactly what love is, Agnes doesn't know whether she loves Boris. In this respect, knowledge is like love. Agnes doesn't know exactly what knowledge is. Since she doesn't know exactly what knowledge is, she doesn't know whether she 100-knows that she has hands. Knowledge is one relation among others. If you don't know whether a condition is required for something to be related to you in a certain way, and a particular thing obviously doesn't satisfy that condition, then you won't know whether the thing is related to you in that way. KK denies this. So KK is wrong.

The defender of KK has one way out. Deny that Dudley and Agnes know they have hands! If they don't know they have hands, then they don't know that they 100-know that they have hands. The KK defender can say that no one who disagrees with them knows anything. This response is consistent; but it is tasteless and offensive.

2 Fragmentation

Our argument had two premises: Dudley only says what he believes, and Dudley never believes what he knows is false.[2] Defenders of KK may try to reject either premise. We'll start with the second premise. Perhaps people can believe something in one sense or 'guise' while knowing it in another sense. On this proposal, Dudley believes under one guise that he does not 100-know that he has hands. He knows under another guise that he does 100-know that he has hands.

The details of this response depend on what guises are. One theory is that guises are fragments. People believe and know things relative to different fragments. Each fragment is activated in different situations. Each fragment is logically closed and internally consistent, and each fragment satisfies KK (Greco 2015b).

For example, perhaps Dudley and Agnes have a classroom fragment and an outside fragment. In the classroom, they have beliefs that guide their philosophical musings; in the outside world, they have other beliefs that guide their ongoing relations with the external world. The beliefs of one fragment can contradict the beliefs of another; but each fragment is internally consistent.

The fragmenter wants to claim that people only deny KK relative to their classroom fragment. But when they are in the outside world, they do not deny KK. Sadly, the fragmenter cannot claim this. The problem is that the defender of KK says that each fragment satisfies KK.

[2] More carefully: we assume that there is a class of agents who deny KK in the way that Dudley does. Our premises are that people in this class only say what they believe, and never believe what they know to be false.

Tim thinks he doesn't 100-know he has hands, because he thinks he doesn't 100-know any empirical truth about the world. The fragmenter interprets Tim as believing this only relative to the classroom fragment. But here's the problem. Presumably Tim knows some empirical truth about the world relative to the classroom fragment. As Tim shouts at you about KK, he points to his hands as an example of something he doesn't 100-know, and he tells you that he does have hands. But if KK holds in the classroom fragment, and if Tim knows he has hands in the classroom fragment, then it immediately follows that he knows in the classroom fragment that he 100-knows he has hands. The KK fragmenter is forced to say that when Tim denies that he 100-knows any empirical truth about the world, he can only do so relative to a fragment that knows zero empirical truths about the world.

Imagine a tougher opponent to KK, who denies that they 100-know anything at all, including even the claim that they believe they fail to 100-know anything. Suppose that their classroom fragment knows some claim p. It follows that their classroom fragment knows they 100-know p. So what explains why this tougher person is in the classroom denying that they 100-know p? The KK fragmenter is forced to say that the tougher opponent knows nothing at all relative to the fragment that denies KK. Again, tasteless and offensive, but now with fragments.

3. Diagonalization

We have explored the prospects of denying the principle that when you believe p, you do not know that p is false. Now consider our other starting premise: that if someone utters the sentence *I don't 100-know I have hands*, then they believe that they don't 100-know that they have hands. One way to deny this premise appeals to the theory of diagonalization (Stalnaker 1978). According to this theory, our beliefs about the non-linguistic world are systematically conflated with beliefs about language. Dudley believes that he has hands. Dudley also believes the sentence *I have hands* is true. Philosophical confusion results from mistaking one kind of belief for the other.

For example, the diagonalizing KK-er will claim that Dudley knows he has hands, and knows that he 100-knows he has hands. Crucially, however, Dudley does not know that the sentence *I 100-know I have hands* is true. Dudley is in the grip of a false theory about the word *know*. He thinks that *know* expresses a relation that does not freely iterate. So Dudley does not know that *I 100-know I have hand*s expresses a truth.

Dudley utters the sentence *I don't 100-know I have hands*. He utters this sentence because he thinks the sentence is true, and Dudley tries his best to say what is true. But he does not actually believe he does not 100-know he has hands.[3]

We are unimpressed. Return to the case of love. Agnes is unsure of what love is, and so she is unsure of whether she loves Boris. Here, the diagonalizer could intervene, arguing that Agnes does know that she loves Boris; Agnes is merely ignorant of the fact that the sentence *Agnes loves Boris* is true. This proposal strikes us as veering towards madness.

[3] Note that the defender of diagonalization must in general deny that people know the disquotation principle that p iff 'p' is true. Otherwise, Dudley could infer from the fact that he knows he hands that the sentence 'he knows he has hands' is true. In place of this principle, the defender of diagonalization should say that Dudley merely knows that the sentence 'p iff 'p' is true' is true.

Does all ignorance about the nature of worldly relations turn out to be ignorance of language? At any rate, we feel strong pressure to analogize Agnes's attitudes towards love and knowledge. If she is ignorant about who she loves, then she can also be ignorant about what she knows.

The diagonalization defense of KK risks undercutting the explanatory power of KK. Consider assertion. Cohen and Comesaña 2013, Greco 2014, and Das and Salow 2018 argue that KK explains why it is strange to say the 'dubious' assertion *I have hands but I don't know that I know I have hand*s. First, assertion is governed by a knowledge norm: I should only say what I know (Williamson 2000). Second, KK predicts that I can't know a dubious assertion: if I know it, then (assuming, plausibly, that knowledge distributes over conjunctions), I know I have hands; so by KK I know that I know I have hands; but then it isn't true that I don't know that I know I have hands.

Now return to the diagonalization defender. They seek to explain why the dubious assertion *I have hands but I don't know that I know I have hands* is strange to say. But Dudley will say a sentence from his own language if he believes he knows the sentence is true, regardless of whether he believes the proposition it expresses. The theory under discussion successfully predicts that Dudley knows that he does not know that: he has hands and doesn't know that he knows he has hands. But the problem is that the theory allows Dudley to believe that he knows that the sentence *I have hands but I don't know that I know I have hands* is true. In that case, he may well assert it.

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Three Rich-Lexicon Theories of Slurs: A Comparison

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Many authors writing on slurs think that they are lexically rich, at least in the sense that their literal or lexical meaning comprises both a descriptive, truth-conditional dimension and an expressive/evaluative one (e.g., Potts 2007; Richard 2008; Predelli 2013; Camp 2013; Jeshion 2013). Appeal to an additional meaning dimension helps accounting for the derogatory character of slurs. However, more fine-grained theories of slurs have been proposed, and they all draw on frameworks and tools from lexical semantics and the theory of concepts. Such theories give a more precise description of the lexical entries of slurs and impose a certain structure on them.

My main aim in this paper is to compare three such fine-grained rich-lexicon theories both vis-à-vis their theoretical commitments and in their ability to explain the whole range of the data they are meant to apply to. As widely known, slurs have a panoply of uses. While the most common is their straightforward *derogatory* use, there are several types of non-derogatory uses of slurs as well. (For examples and contributions to the literature on this type of use of slurs, see Cepollaro & Zeman (2020).) *Re-appropriated* (the n-word; "queer"), *corrective* ("Institutions that treat Chinese as c*** are morally depraved." Hom, 2008: 423), *referential* (certain forms of the n-word, according to Anderson 2018), *metaphorical* ("Woman is the n*** of the world.", John Lennon & Yoko Ono) and *didactical* uses all are of this kind. In addition, certain ethnic slurs (e.g., "țigan" in Romanian) have what can be called *identificatory* uses – when a slur is used by members of the target group to non-derogatorily identify as an ethnic group (Zeman 2020).

The view I prefer is a rich-lexicon theory that takes the lexical meaning of slurs to be composed of an extension and a conceptual structure (on the model of Del Pinal's 2018 framework). Among the meaning dimensions of the conceptual structure are the usual ones found in nouns (information about perceptual information about the objects referred to, about what they are made of or their parts, about how they came to being, about the purpose of their creation, about their typical function etc.), but also, because the targets of slurs belong to a certain group, information about their provenance, history, social standing etc. Crucially, such lexical entries comprise an *evaluative* dimension, which is responsible for the derogatory character of slurs. While the lexical entry of a slur comprises the entire conceptual structure with all the meaning dimensions, in particular uses of slurs different dimensions get *foregrounded/backgrounded*. Thus, when a slur is used derogatorily, the evaluative dimension is foregrounded and the others backgrounded. When the same slur is used in a referential or identificatory manner, the evaluative dimension is backgrounded, while others are foregrounded. (In re-appropriated uses, the evaluative dimension is still foregrounded, but the valence of the evaluation is switched.) According to this view, then, slurs are polysemous, and their variation in meaning across contexts is construed as polysemy resolution, which is done via the mechanisms of foregrounding and backgrounding mentioned.

At least a couple of similar views can be found in the literature. For Croom 2011, 2013, slurs encode rich conceptual structures that have as their meaning dimensions *properties*, both positive and negative, that the prototypical members of the target groups are taken to possess. While there is no essential property that all members of the target group need to share for a slur to apply, different members share some of the properties associated with them. These properties are ranked; this ranking, however, is context-sensitive and helps in communicating with slurs: a speaker selects among the properties in question those which are suitable for a given communicative situation. When a slur is used derogatorily, the negative properties prototypical members of the target group are taken to have are selected. When a slur is used in a re-appropriated manner, the positive properties prototypical members of the target group are taken to have are selected. (Croom doesn't consider referential or identificatory uses of slurs, but one can extrapolate from the above how they would be treated: none of the positive or the negative properties from the list are selected, only neutral properties like mere membership of the relevant group.)

One worry one might have about Croom's view is that it is too unrestricted: the list of properties associated with a slur is open, and thus can end up being quite substantive. This has the potential to create trouble when it comes to storing and computing slurs. A view that postulates fewer, better regimented, meaning dimensions might fare better on this score. Second, Croom claims that the selection of properties in a given context is based on *closeness to the members of the target group* and are supposed to serve only communicative purposes. Yet, there are cases in which the use of a slur is restricted by the linguistic material of the sentences in which is appears. For example, one cannot use the n-word in a re-appropriated manner in a sentence stating the results of a census, even if the speaker is very close to the members of the target group.

Neufeld 2019, 2022 proposes an *"essentialist"* theory of slurs, according to which they are terms with null extension. The novelty of the view consists in the claim that part of the meaning dimensions of a slur is an "essence" that is given a causal-explanatory role for the negative traits that members of the target group are taken to possess. That is, what explains and causes the members of the target group to have the negative traits perceived is precisely this "essence" ("blackness", "queerness" etc.); but since no such real essences exist, the terms fail to refer. The view differs from Croom's in taking the meaning dimensions to be related in a precise way (the "essences" cause the negative properties).

Neufeld doesn't consider re-appropriated, referential or identificatory sues of slurs, and it's not straightforward how these are to be accounted for in her view. In fact, there might be a possible problem with extending the view to such uses. Since the "essences" that "cause" the negative properties ascribed to the targets don't exist, slurs have null extension. However, slurs don't seem to have null extensions when used in the ways mentioned above (sentences in which slurs are used in those ways strike us/their users as true). What happens with the "essence" in such cases? It would be weird to claim that it simply disappears. A view that postulates some selection mechanisms (like foregrounding and backgrounding) has an easier answer to this issue.

Further, the postulation of an "essence" in the lexical entry of slurs might also lead to problems. Neufeld cites a lot of psychological evidence according to which essentialization is a core characteristic of humans' conceptual ability. Yet, I wonder whether her view allows for users of slurs that are not committed to, or even explicitly reject, any "essences". Thus, imagine a social constructivist who thinks that race is not something people "essentially" possess, but determined by the milieu in which one grows up. They might hold that the traits associated with a given race are not immutable, but that, as a matter of statistics, the traits that most members of a certain racial group possess are negative. Now, as it happens, our social constructivist is also a racist. When our racist social constructivist uses a slur, they seem to be employing it without appeal to any "essence". Such racist social constructivists seem conceivable/possible, but it is not clear whether Neufeld can make room for them in her theory. This is not a problem for the other two rich-lexicon theories considered.

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Contrafactives and learnability*

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Holton (2017) has drawn attention to a novel semantic universal, according to which (at least almost) no natural language features contrafactive attitude verbs. Contrafactives are the mirror image of factive attitude verbs like *know*, *remember*, *see*, and *regret*: although both factives and contrafactives entail a belief, contrafactives differ from factives in presupposing the falsity, as opposed to the truth, of that belief. So, whilst both *Dan knows that it is raining* and *Dan contrafactives that it is raining* entail that Dan believes that it is raining, the former also presupposes that it is raining, whereas the latter presupposes that it is not. Although some candidate contrafactives have been discussed (see Holton, 2017, pp.245-9, 262–4), no clear counterexample to the universal has been found: for instance, Anvari, Maldonado, and Soria Ruiz (2019)'s *creerse* is built by adjoining the reflexive pronoun to the non-factive verb *creer* 'believe', the falsity inference of Hsiao (2017)'s Taiwanese Southern Min verb *liah-tsun* is too easy to cancel, and Glass (2022)'s Mandarin belief verb *yǐwéi* carries a post-, rather than presupposition, that the reported belief must not be added to the common ground.

The no contrafactives universal raises an important question: why do natural languages universally feature factive verbs like *know* (Goddard, 2010; Haspelmath and Tadmor, 2009), but (at least almost) universally lack contrafactives? We develop a novel explanation of at least part of this asymmetry. Drawing on recent discussions of other semantic universals, such as the veridical uniformity universal for responsive verbs (Steinert-Threlkeld, 2019), the conservativity, monotonicity, and quantity universals for determiners (Steinert-Threlkeld and Szymanik, 2019), and the convexity universal for color terms (Steinert-Threlkeld and Szymanik, 2020), we explore the hypothesis that the asymmetry between contrafactives and factives arises at least in part because the meaning of a contrafactive is harder to learn than that of a factive. We tested this hypothesis by conducting a computational experiment using an artificial neural network. As we explain below, the results of the experiment support our hypothesis.

Our hypothesis is inspired by the intuitive idea that languages have words for meanings that are easier to learn and use compositional methods to express meanings that are harder to acquire (Steinert-Threlkeld and Szymanik, 2019, p.4). This intuitive idea can be applied to the asymmetry between factives and contrafactives. Since a factive presupposes the truth of its *that*-complement, a factive attitude ascription represents the way the subject of the ascription takes the world to be and the way the world is, according to the ascriber, as converging. By contrast, since a contrafactive presupposes the falsity of its *that*-complement, a contrafactive attitude ascription represents the way the subject of the ascription takes the world to be and the way the world is, according to the ascriber, as *diverging*. A factive attitude ascription thus only requires ascribing (part of) one's own take on how things are to another person. By contrast, a contrafactive attitude ascription requires ascribing a take on how things are to another person that is inconsistent with one's own. This is a more complex achievement that we expect to be harder to learn (cf. Phillips and Norby, 2021). Given that this difference between factive and contrafactive attitude ascription appears to be due entirely due to the meaning of factives and contrafactives, this difference leads us to expect that the semantics of contrafactives is harder to acquire than that of factives.

*This paper reports on research supported by Cambridge University Press and Assessment, University of Cambridge. We thank the NVIDIA Corporation for the donation of the Titan X Pascal GPU used in this research. Simon Wimmer's work on this paper was supported by a postdoc stipend of the Fritz Thyssen Foundation.

To test our expectation, we conducted a computational experiment using an artificial neural network. This network was trained to predict the truth value of factive, non-factive or contrafactive attitude ascriptions, given a representation of a small world and a representation of the small world as the attitude holder takes it to be (which may or may not be accurate). The network's prediction was expressed in a probability that the target ascription is true. The artificial language in which the target attitude ascriptions were formulated and which the neural network learned can be interpreted as a fragment that describes propositions about the relative locations of two objects to each other plus the attitude taken towards these propositions. To encode this artificial language and the representations, we used a Transformer encoder. Transformers, which are based upon the so-called attention mechanism that allows contextualised processing of word information, are the foundation of current state-of-the-art results in natural language processing (Vaswani et al., 2017; Devlin et al., 2019; Rogers, Kovaleva, and Rumshisky, 2020).

Generally speaking, the results of our experiments show the Transformer-encoder to perform better on factive verbs than contrafactive verbs. While the performance on non-factive verbs was even worse, we consider this to be at least in part the result of the architecture being not well-suited for these verbs. The architecture always processes both a mind and a world representation, even though the latter only contributes noise in the case of non-factive verbs. We assume that the human brain incorporates a better input-gating mechanism than our model, which would increase the performance on non-factive verbs. In the following, we report the results for the comparison between factive and contrafactive verbs.

We evaluated 51 hyperparameter settings in an initial search, 18 of which performed below 60% accuracy and 27 exceeded 90% accuracy. In all except 4 of the 51 settings, the accuracy was higher for the factive than the contrafactive verb (but not significantly so). We take this to suggest that the difference is due to the neural architecture rather than the hyperparameters.

The setting which performed best in the hyperparameter search, i.e. the one with the highest overall accuracy, was then applied to a hold-out test set. The results on this test set once again showed higher performance for the factive than the contrafactive verbs. The difference in accuracy was small, because the model was trained on a large sample of data.

The differences for the mean absolute error are larger. In particular, the error is significantly larger for contrafactive verbs than factive ones ($p < 0.01$), see figure 1. The training for the factive verb also proceeded faster than for the contrafactive verb, see figure 2, providing further support for a difference in how hard it is to learn the meaning of a contrafactive as opposed to factive. To provide some numbers for intuition, after 100000 training examples the average loss of the factive predicate is 0.39, while the one for the contrafactive predicate is 0.54.

Post-experimental analysis suggests that the presence or absence of potentially confusing objects in the world and mind representation was responsible for much of the remaining errors. That is, the network was paying excessive attention to whether objects named in the artificial language sentences were present or not, ignoring whether the described relationship between the objects held. Given this, we plan to carry out a follow-up experiment in which the artificial language which the neural network learns is simpler, being roughly interpretable as a fragment that simply describes a primitive, non-decomposable proposition and the attitude taken toward that proposition.

Our computational experiment improves on similar ones conducted by Steinert-Threlkeld (2019) and Steinert-Threlkeld and Szymanik (2019) in a number of ways. First, we report results from a larger range of hyperparameters (e.g. training epochs, learning rate, etc.). By exploring the range of models which bear out our expectation that contrafactives are harder to learn than factives, we provide a better sense of the robustness of our experimental results. Second, while the cited research used feed-forward neural networks and LSTMs, we switched to the more advanced Transformer-architecture. Recent results suggest that despite not being originally designed for cognitive plausibility, Transformer-based networks nonetheless show greater convergence with human processing than other approaches (e.g. Caucheteux and King, 2022). Given this, the results of our computational experiment likely reflect learnability for human language learners more closely than previous work.

However, the results from our experiment likely capture only one source of a difference in learnability between factives and contrafactives. Our results do not reflect pragmatic and syntactic features, since the input sentences do not differ in this regard. But these features likely contribute to the difference in learnability of factives and contrafactives. To illustrate, on the pragmatic syntactic bootstrapping model of how infants acquire attitude verb meanings (Hacquard and Lidz, 2022), the meaning of non-factive *think* is partly inferred from the parallel between the use of *I think P* as an indirect assertion and the primary use of *P* as an assertion, and the meaning of factive *know* is partly inferred from the parallel between the use of *Do you know Q?* as an indirect question and the primary use of *Q?* as a question. Yet unlike in the case of factive and non-factive verbs, no such parallels would hold for a contrafactive: use of a contrafactive attitude ascription would not match the primary use of its complement. We leave it to future work to explore how this pragmatic syntactic difference between factive, non-factive, and contrafactive attitude ascriptions and the differences suggested by our computational experiment combine to explain the difference in frequency of factive, non-factive, and contrafactive verbs in natural languages.

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Figures

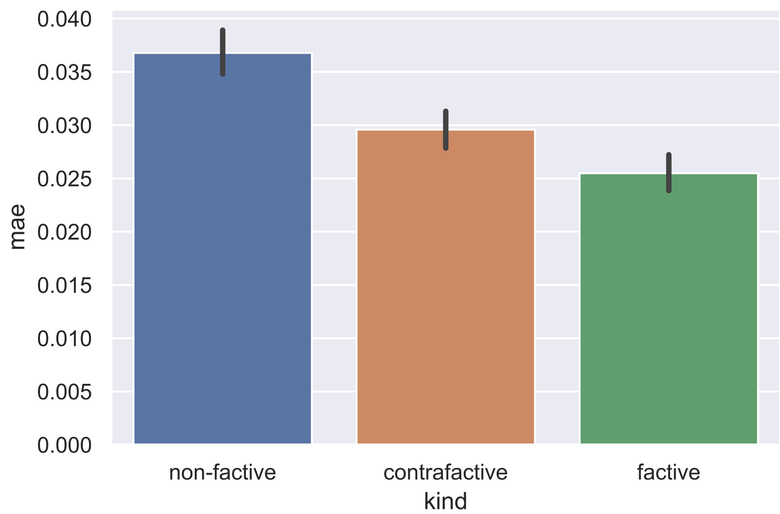

Figure 1: Mean absolute error on test set for all three types of predicates.

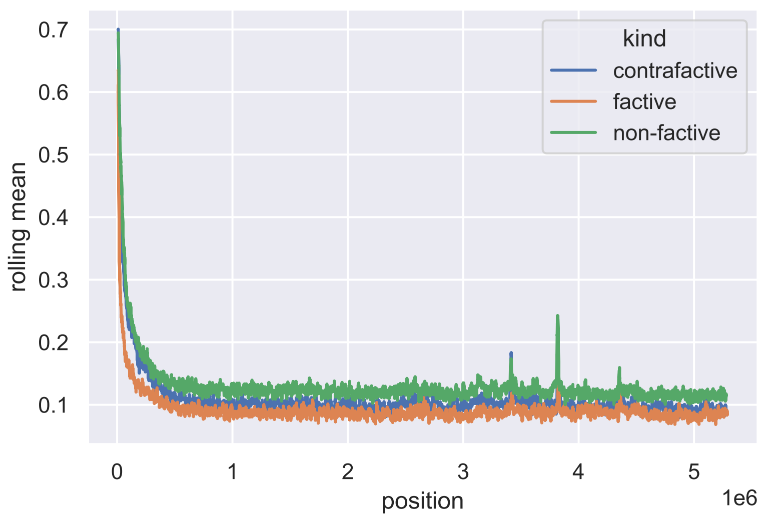

Figure 2: Rolling loss smoothed over 10000 instances during training on complete training set.

Gricean Pragmatics According to Himself

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Grice presents the theory of conversational implicature based on the cooperative principle and conversational maxims in his 1975 paper. Typically, Gricean pragmatics refers to a range of pragmatic theories that account for various cases of conversational implicature by relying on various conversational maxims. However, it is unclear what Grice himself would think a pragmatic theory of conversational implicature should be beyond what he stated in his 1975 article.

The following four points must be noted to understand Grice's perspective on conversational implicature: (1) he classifies conversational implicature as falling under the category of speaker meaning (or "utterer's meaning" in his original term), (2) the concept of speaker meaning is understood in terms of the concept of speaker's intention, (3) he believes that the concept of intention is analyzable in terms of the concepts of will and belief, (4) his perspective on psychological states such as will and belief is based on his unique axiomatic philosophy of mind.

As Grice explained in his papers from 1968 and 1969, his analysis of speaker meaning is supposed to provide a basis for his theory of implicature. He attempts to provide the individually necessary and jointly sufficient conditions for one's meaning something in terms of their intentions: a speaker, S, (indicatively) means that p by uttering x if and only if S utters x intending (1) an audience, A, to believe that p, (2) A to realize that S intends (1), and (3) A's realizing that S intends (1) is a part of their reason to believe that p. Thus, what one means by their utterance, and therefore what they conversationally implicate, is essentially a matter of what they intend.

Grice argues that intention is a complex psychological state composed of two simpler states: will and belief. Thus, what one intends is essentially a matter of what they will and believe. It means that what a speaker conversationally implicates is supposed to be determined by their wills and beliefs. According to Grice, psychological states such as will and belief are understood as something that provides an "explanatory bridge" between the situation an agent is put in and what they do in that situation. According to Grice, to explain an agent's action is to provide a deductive inference with the premise that they are in such and such a situation and with the consequence that they do the action in question. In order to make such an inference, we must fill in the gaps between the premise and the consequence. Thus, we must rely on certain axioms. Psychological states, according to Grice, appear in such axioms.

With this overview of Grice's philosophical system, it is that Gricean pragmatics as Grice himself envisions would be a search for our psychological axioms that eenable our mutual understanding in everyday communication.