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Searching for a universal constraint on the possible denotations of clause-embedding predicates*

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Abstract We propose a new cross-linguistic constraint on the relationship between the meaning of a clause-embedding predicate when it takes an *interrogative complement* and its meaning when it takes a *declarative complement*. According to this proposal, every clause-embedding predicate V satisfies a constraint that we refer to as P-TO-Q ENTAILMENT. That is, for any exhaustivity-neutral interrogative complement Q , if there is an answer p to Q such that $\lceil x \text{ Vs } p \rceil$, then it follows that $\lceil x \text{ Vs } Q \rceil$. We discuss empirical advantages of this proposal over existing proposals and explore potential counterexamples to P-TO-Q ENTAILMENT.

Keywords: clause-embedding predicates, cross-linguistic semantics, linguistic universals.

1 Introduction

A central question in semantics is whether there are any universal constraints on the possible denotations of lexical items of certain grammatical categories. This question has been investigated most prominently in the domain of determiners. For instance, it has been proposed that all determiners are ‘conservative’ and that all monomorphemic determiners are ‘monotonic’ (Barwise & Cooper 1981).

Recent work has explored semantic universals in the domain of clause-embedding predicates like *know*, *agree*, and *wonder* (Spector & Egré 2015; Theiler, Roelofsen & Aloni 2018; Uegaki 2019; Steinert-Threlkeld 2020). Within this line of work, two basic questions can be distinguished. The first is empirical: Which constraints, if any, do we find in the semantics of clause-embedding predicates? The second is theoretical: What may explain such universal semantic constraints? The present paper is primarily concerned with the first question.

More specifically, we will consider a number of recent proposals which put forward possible constraints that relate the meaning of a clause-embedding predicate

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when it takes an *interrogative complement* to its meaning when it takes a *declarative complement* (Spector & Egré 2015; Theiler et al. 2018; Uegaki 2019). We will identify counterexamples for each of these proposals, and will formulate a new constraint, P-TO-Q ENTAILMENT, which *rules in* the counterexamples to existing proposals and yet *rules out* many conceivable denotations which have so far not been attested in cross-linguistic research.

The paper is structured as follows. §2 discusses existing proposals, §3 evaluates these, and §4 introduces P-TO-Q ENTAILMENT. §5 discusses a number of empirical observations in recent cross-linguistic work which suggest potential counterexamples to the proposed constraint, though in each case further empirical work is needed to establish the exact status of the relevant constructions. §6 concludes.

2 Existing proposals

2.1 Veridical Uniformity

Spector & Egré (2015) (henceforth, S&E) propose that all responsive clause-embedding predicates (that is, predicates that take both declarative and interrogative complements) are ‘uniform w.r.t. veridicality’. To spell out what this means, let us first recall when a predicate is veridical w.r.t. declarative/interrogative complements.

A predicate V is veridical w.r.t. declarative complements if and only if for every declarative complement p :

$$(1) \quad \lceil x Vs p \rceil \Rightarrow \lceil p \rceil$$

For instance, *know* is veridical because:

$$(2) \quad \text{Mary knows that Bill left} \Rightarrow \text{Bill left}$$

Veridicality w.r.t. interrogative complements is somewhat more involved. We follow Theiler et al. (2018) in defining this notion in terms of so-called *exhaustivity-neutral* interrogative complements. Interrogative complements often allow for multiple readings that differ in the level of exhaustivity (non-exhaustive, weakly exhaustive, intermediate exhaustive, strongly exhaustive). Exhaustivity-neutral interrogative complements are ones for which all these readings coincide. They include polar interrogatives like $\lceil \text{whether Bill left} \rceil$, as well as wh-interrogatives with a uniqueness presupposition such as $\lceil \text{which boy left} \rceil$. For such exhaustivity-neutral interrogative complements it is clear which propositions contain precisely enough information to resolve the issue expressed by the interrogative. We refer to declarative complements expressing such propositions as *answers*. For instance, the answers to $\lceil \text{whether Bill left} \rceil$ are $\lceil \text{that Bill left} \rceil$ and $\lceil \text{that Bill didn't leave} \rceil$.

A predicate V is *veridical w.r.t. interrogative complements* if and only if for

every exhaustivity-neutral interrogative complement Q and any answer p to Q :

$$(3) \quad \lceil x \text{ Vs } Q \rceil \ \& \ \lceil p \rceil \Rightarrow \lceil x \text{ Vs } p \rceil$$

For instance, *know* is veridical w.r.t. interrogative complements because:¹

$$(4) \quad \text{Mary knows whether Bill left} \ \& \ \text{Bill left} \Rightarrow \text{Mary knows that Bill left}$$

A responsive predicate is uniform w.r.t. veridicality if and only if it is either veridical w.r.t. both declarative and interrogative complements, or non-veridical w.r.t. both declarative and interrogative complements. S&E propose the following generalization:

- (5) VERIDICAL UNIFORMITY
All responsive predicates are uniform w.r.t. veridicality.

Note that *know* is indeed uniform w.r.t. veridicality. As an example of a predicate that does *not* satisfy this property, S&E consider the fictitious verb *shknow*, meaning ‘know’ when taking a declarative complement and ‘wonder’ when taking an interrogative complement. *shknow* would be veridical w.r.t. declarative complements, but not w.r.t. interrogative complements. VERIDICAL UNIFORMITY predicts that such predicates do not exist in any language.

2.2 Clausal distributivity

Theiler et al. (2018) consider another constraint on clause-embedding predicates, which is formulated in terms of a property they refer to as ‘clausal distributivity’ (c-distributivity for short). A clause-embedding predicate V is c-distributive just in case for any exhaustivity-neutral interrogative complement Q :

¹ As pointed out in Theiler et al. 2018, if we had not restricted ourselves to exhaustivity-neutral complements in the definition of veridicality w.r.t. interrogative complements, then *know* would have been classified as *non-veridical*. To see this, consider the following example, in which the complement has a salient non-exhaustive (mention-some) reading.

- (i) Rudolph knows where one can buy an Italian newspaper.

Suppose that Rudolph knows that one can get an Italian newspaper at Newstopia, and that he does not falsely believe that one can get Italian newspapers elsewhere. Further suppose that in fact Italian newspapers are sold both at Newstopia and at Paperworld. Then, on the one hand, (i) is true on a non-exhaustive reading. On the other hand, *that one can get an Italian newspaper at Paperworld* is an answer to the embedded interrogative (still assuming a non-exhaustive reading). But (ii) is false, violating the requirement for veridicality w.r.t. interrogative complements.

- (ii) Rudolph knows that one can buy an Italian newspaper at Paperworld.

- (6) $\lceil x \text{ Vs } Q \rceil \Leftrightarrow$ there is an answer p to Q such that $\lceil x \text{ Vs } p \rceil$

For instance, *know* is c-distributive since $\lceil \text{Jo knows whether Sue left} \rceil$ is true if and only if $\lceil \text{Jo knows that Sue left} \rceil$ or $\lceil \text{Jo knows that Sue didn't leave} \rceil$ is true. On the other hand, *shknow* is not c-distributive since $\lceil \text{Jo shknows whether Sue left} \rceil$ does not imply that either $\lceil \text{Jo shknows that Sue left} \rceil$ or $\lceil \text{Jo shknows that Sue didn't leave} \rceil$ is true (in fact, it implies that both are false).

- (7) C-DISTRIBUTIVITY
All responsive clause-embedding predicates are c-distributive.

Theiler et al. (2018) note that *predicates of relevance* (PoRs) such as *care* and *matter* form counterexamples to both VERIDICAL UNIFORMITY and C-DISTRIBUTIVITY. They are counterexamples to VERIDICAL UNIFORMITY because they are veridical w.r.t. declaratives but not w.r.t. interrogatives. They are counterexamples to C-DISTRIBUTIVITY since (8a) can be true without either (8b) or (8c) being true (Elliott, Klinedinst, Sudo & Uegaki 2017):

- (8) a. It matters to Jo whether Sue left.
b. It matters to Jo that Sue left.
c. It matters to Jo that Sue didn't left.

Uegaki (2019) notes that it is the *presuppositional* component of predicates of relevance that makes them counterexamples to C-DISTRIBUTIVITY. (8b) presupposes that Sue left and (8c) presupposes that Sue didn't leave, while (8a) does not guarantee that any of these presuppositions is satisfied. Uegaki proposes a variant of C-DISTRIBUTIVITY which is formulated in terms of Strawson entailment (von Stechow 1999) rather than plain entailment and thereby successfully rules in predicates of relevance. The problems discussed below, however, apply to STRAWSON C-DISTRIBUTIVITY just as much as they do to plain C-DISTRIBUTIVITY.

3 Problematic cases

3.1 Estonian *mõtlema*

Roberts (2018) presents a detailed investigation of the Estonian responsive clause-embedding predicate *mõtlema*. When φ is a declarative complement, $\lceil x \text{ mõtlema } \varphi \rceil$ has two possible readings. Under what we will call its 'believe reading' it simply means that x believes φ . Under its 'imagine reading', on the other hand, it means that x believes not- φ but imagines what the world would be like if φ were true. These two interpretations are exemplified in (9) and (10), respectively:

- (9) Liis mõtleb, et sajab vihma, aga ei saja.
 Liis MOTLEMA that falls rain but NEG fall.NEG
 ‘Liis thinks that it’s raining, but it isn’t raining.’
- (10) *Context: I am discussing with my friend what life would be like if an asteroid had not collided with the earth at the end of the late Cretaceous period.*
 Ma mõtlen, et dinosaurused on ikka elus, kuigi ma tean, et
 I MOTLEMA that dinosaurs are still alive although I know that
 ei ole.
 NEG be.NEG
 ‘I’m thinking about dinosaurs still being alive, even though I know that they aren’t.’

When φ is an interrogative complement, $\lceil x \text{ mõtlema } \varphi \rceil$ also has two possible readings. Under the ‘wonder reading’ it means that x wonders what the answer to φ is. On the other hand, under the ‘imagine reading’ it means that for some answer p to φ , x believes not- p but imagines what the world would be like if p were true. The first interpretation is exemplified in (11), the second in (12).

- (11) Ma mõtlen, kes ukse taga on.
 I MOTLEMA who door behind is
 ‘I wonder who is at the door.’
- (12) *Context: Liis hears a knock at the door. She was expecting her friend Kirsi to come over, but she fantasizes for just a moment all the famous celebrities who could be showing up instead.*
 Liis mõtleb, kes ukse taga on, kuigi ta teab, et on Kirsi.
 Liis MOTLEMA who door behind is although she knows that is Kirsi
 ‘Liis is thinking about who is at the door, even though she knows it’s Kirsi.’

To see that this predicate violates C-DISTRIBUTIVITY consider a context in which (i) Mary believes neither that it is raining nor that it is not raining; and (ii) she wants to know whether it’s raining. Now consider the following statements:

- (13) a. Mary mõtlema whether it is raining.
 b. Mary mõtlema that it is raining.
 c. Mary mõtlema that it isn’t raining.

In the given context, according to Roberts’ empirical description, (13a) is **true** (on the ‘wonder’ reading), (13b) is **false** (on either the ‘believe’ or the ‘imagine’ reading), and (13c) is **false** (on either the ‘believe’ or the ‘imagine’ reading). This means that *mõtlema* violates C-DISTRIBUTIVITY. It also violates STRAWSON

C-DISTRIBUTIVITY, as presuppositions do not play a role in the counterexample.

Roberts (2018) notes that *mõtlemä* is not alone in this kind of behavior: similar patterns can be observed with Estonian *mõtisklemä* ‘consider’, *vaatlemä* ‘observe’, and *meelisklemä* ‘muse’, as well as Finnish *mieltiä*, a presumed cognate of *mõtlemä*.

3.2 Japanese *daroo*

The Japanese sentence-final particle *daroo*, as analysed by Hara (2018) and Uegaki & Roelofsen (2018), also constitutes a counterexample to C-DISTRIBUTIVITY. This particle can have either a declarative or an interrogative prejacent. With a declarative prejacent, its meaning is similar to *think*.

- (14) Ken-wa utau daroo.
Ken-TOP sing DAROO
‘I think that Ken will sing.’

With an interrogative prejacent, its meaning is similar to *wonder* (a subtle difference with *wonder* will be discussed later but is not relevant here yet).

- (15) Ken-wa utau daroo-ka.
Ken-TOP sing DAROO-Q
‘I wonder whether Ken will sing.’

To see that *daroo* violates C-DISTRIBUTIVITY consider a context in which Mary would like to know whether Ken will sing (and doesn’t know yet). In such a context, Mary can truthfully utter (15) but not (14), nor a variant of (14) in which the prejacent is negated. This shows that *daroo* violates C-DISTRIBUTIVITY. Again, STRAWSON C-DISTRIBUTIVITY is violated as well since presuppositions do not play a role here.

3.3 Inquisitive predicates

Inquisitive predicates like *wonder* and *inquire* also constitute a challenge for C-DISTRIBUTIVITY, though at a somewhat different level than *daroo* and *mõtlemä*. Since *wonder* and *inquire* are rogative predicates—i.e., they only take interrogative complements—we might simply assume that a constraint like C-DISTRIBUTIVITY does not apply to such predicates, since the constraint makes reference to cases in which the predicate combines with a declarative complement. In principle, however, it would be preferable to think of the constraint as applying across clause-embedding predicates, without making reference to selectional restrictions. And this is possible if, following Ciardelli & Roelofsen (2015) and Uegaki (2015), we assume that rogative predicates like *wonder* are of the same semantic type as responsive predicates like *know*. For concreteness, consider the following entry:

	<i>know</i>	<i>*shknow</i>	<i>care</i>	<i>mōtlema</i>	<i>daroo</i>	<i>wonder</i>
VERIDICAL UNIFORMITY	✓	✓	✗	✓	✓	NA
C-DISTRIBUTIVITY	✓	✓	✗	✗	✗	✗
STRAWSON C-DISTRIBUTIVITY	✓	✓	✓	✗	✗	✗

Table 1 Summary of the predictions of the three constraints discussed so far.

$$(16) \quad \llbracket \text{wonder} \rrbracket^w = \lambda Q \lambda x. \text{DOX}_x^w \notin Q \wedge \text{INQ}_x^w \subseteq Q$$

where (i) we take a complement Q to denote a set of propositions, namely those propositions that resolve the issue expressed by Q ; (ii) DOX_x^w is the doxastic state of x in w , that is, the set of worlds that x considers possible in w ; and (iii) INQ_x^w is the inquisitive state of x in w , that is, the set of subsets of DOX_x^w in which the issues that x entertains in w are resolved.

The entry says that $\lceil x \text{ wonders } \varphi \rceil$ is true in w just in case (i) x 's doxastic state is not an element of the semantic value of φ , which means that it does not resolve the issue expressed by φ , and (ii) x 's inquisitive state is contained in the semantic value of φ , which means that x would like to reach a doxastic state which does resolve the issue expressed by φ .

In principle, φ can be a declarative complement. In this case, however, the two conjuncts in the entry for *wonder* always contradict each other. That is, the entry predicts that, when φ is a declarative complement, $\lceil x \text{ wonders } \varphi \rceil$ is always contradictory. Indeed, this is how the selectional restrictions of *wonder* are accounted for in Ciardelli & Roelofsen 2015 and Uegaki 2015.

On such an account, it is possible to evaluate whether *wonder* satisfies C-DISTRIBUTIVITY. And the answer is that it doesn't. After all, $\lceil x \text{ wonders } Q \rceil$ can be true even if for every answer p to Q , $\lceil x \text{ wonders } p \rceil$ is false. The latter, in fact, holds for any p whatsoever. Again, the problem applies equally to STRAWSON C-DISTRIBUTIVITY.

Interim summary The cases discussed so far are summarised in Table 1, where ✓ means 'correct prediction' and ✗ means 'incorrect prediction'.

4 Proposal

We have seen that previously proposed constraints on the denotations of clause-embedding predicates face empirical challenges. We now formulate a new constraint, P-TO-Q ENTAILMENT, which overcomes these empirical challenges. We say that a clause-embedding predicate V is P-TO-Q ENTAILING if and only if for

any exhaustivity-neutral interrogative complement Q , if there is an answer p to Q such that $\lceil x \text{ Vs } p \rceil$, then it also holds that $\lceil x \text{ Vs } Q \rceil$.

(17) P-TO-Q ENTAILMENT

All clause-embedding predicates V are P-TO-Q ENTAILING.

P-TO-Q ENTAILMENT is weaker than (STRAWSON) C-DISTRIBUTIVITY since it is limited to the direction from declarative-embedding to interrogative-embedding. Because of this, all predicates that satisfy the latter (e.g., *know*, *predict*, *surprise*) satisfy the former as well. Moreover, as we will argue in Sections 4.2-4.5, P-TO-Q ENTAILMENT *rules in* attested predicates that are problematic for C-DISTRIBUTIVITY: predicates of relevance, *mõtlema*, *daroo*, and inquisitive predicates. On the other hand, P-TO-Q ENTAILMENT still *rules out* fictitious predicates like *shknow*. These are discussed in Section 4.6. Before discussing these predictions in detail, we will first provide a more precise formulation of P-TO-Q ENTAILMENT in Section 4.1.²

4.1 Formalization

We will provide a formalization of P-TO-Q ENTAILMENT in inquisitive semantics (Ciardelli, Groenendijk & Roelofsen 2018). A similar formalization could be given in Hamblin semantics (Hamblin 1973). In both frameworks, declarative and interrogative clauses are treated uniform. Specifically, the semantic value of a clause φ , $\llbracket \varphi \rrbracket$, is taken to be a set of propositions, no matter whether φ is declarative or interrogative. In inquisitive semantics, $\llbracket \varphi \rrbracket$ is construed as the set of those propositions that (a) resolve the issue that φ expresses (if any); and (b) do not contain any possible worlds that are ruled out by the information that φ conveys (if any). The set of propositions associated with a clause construed this way is always downward closed. That is, if $\llbracket \varphi \rrbracket$ contains a proposition p then it must also contain any stronger proposition $q \subset p$.³ Below are examples of the denotations of declarative and interrogative clauses in this framework:

² P-TO-Q ENTAILMENT relates to VERIDICAL UNIFORMITY as follows. Any P-TO-Q ENTAILING predicate that has the CHOICE PROPERTY, defined in (i) below, and is veridical w.r.t. interrogatives is also veridical w.r.t. declaratives.

- (i) A declarative-embedding predicate V has the CHOICE PROPERTY just in case for any two mutually inconsistent declarative complements p and p' , $x \text{ Vs } \textit{that } p$ and $x \text{ Vs } \textit{that } p'$ cannot be true at the same time.

The proof of this is a straightforward adaptation of the one in Appendix B.3 of Theiler et al. 2018. However, it is not the case that any P-TO-Q ENTAILING predicate that is veridical w.r.t. declaratives is also veridical w.r.t. interrogatives. Counterexamples include predicates of relevance.

³ On this point, Hamblin semantics differs from inquisitive semantics. For comparison, see Roelofsen 2013; Ciardelli, Roelofsen & Theiler 2017; Ciardelli & Roelofsen 2017.

- (18) a. $\llbracket \text{that Ann left} \rrbracket = \{ \{ w \mid \text{Ann left in } w \} \}^\downarrow$
 b. $\llbracket \text{whether Ann left} \rrbracket = \left\{ \begin{array}{l} \{ w \mid \text{Ann left in } w \}, \\ \{ w \mid \text{Ann didn't leave in } w \} \end{array} \right\}^\downarrow$
 where $Q^\downarrow := \{ q \mid q \subseteq p \text{ for some } p \in Q \}$

We will often refer to the maximal elements of $\llbracket \varphi \rrbracket$ as the *alternatives expressed by φ* . These propositions contain precisely enough information to resolve the issue expressed by $\llbracket \varphi \rrbracket$. For any set of propositions Q we write $\text{alt}(Q)$ for the set of maximal elements of Q :

- (19) $\text{alt}(Q) := \{ p \in Q \mid \text{there is no } q \in Q \text{ such that } p \subset q \}$.

With this background, we can formally define P-TO-Q ENTAILING predicates and the P-TO-Q ENTAILMENT constraint as follows:⁴

- (20) A predicate V of type $\langle \langle st, t \rangle, et \rangle$ is P-TO-Q ENTAILING if and only if for any term x and any exhaustivity-neutral Q :
 there is a $p \in \text{alt}(Q)$ such that $\llbracket V \rrbracket(\{p\}^\downarrow)(x) \implies \llbracket V \rrbracket(Q)(x)$
- (21) P-TO-Q ENTAILMENT
 All predicates of type $\langle \langle st, t \rangle, et \rangle$ are P-TO-Q ENTAILING.

In the next four subsections, we will show that the predicates that are problematic for previously proposed constraints, i.e. predicates of relevance, *mõtlema*, *daroo* and *wonder*, satisfy P-TO-Q ENTAILMENT as formulated in (20)-(21).

4.2 Predicates of relevance

For concreteness, we will focus on one predicate of relevance, namely *care*. The discussion below equally applies to other predicates of relevance.

First we note that *care* empirically satisfies P-TO-Q ENTAILMENT, since all variants of (22a) entail (22b).

- (22) a. Ann cares that Peter left. b. Ann cares (about) which boy left.

Next we consider a formal analysis of *care*, and check whether that satisfies P-TO-Q ENTAILMENT as well. We adopt the lexical entry in (23), based on Elliott et al. 2017 and Theiler et al. 2018:

⁴ Here, we give an inquisitive semantic treatment of *complements* (with type $\langle st, t \rangle$), but a traditional treatment of *matrix sentential denotations* (type t). This is merely for expository purposes.

$$(23) \quad \llbracket \text{care} \rrbracket^w = \lambda Q \lambda x : \text{DOX}_x^w \subseteq \bigcup Q. \exists p \in \text{alt}(Q) : \text{BOU}_x^w \subseteq p \vee \text{BOU}_x^w \cap p = \emptyset$$

where BOU_x^w is the set of worlds compatible with x 's preferences in w .

This lexical entry successfully captures the fact that *care* violates C-DISTRIBUTIVITY in the direction from interrogative-embedding to declarative-embedding, as discussed in Section 2.2. Specifically, (23) captures the fact that (22b) has a very weak presupposition (Ann believes that some boy left), while (22a) has a much stronger presupposition (Ann believes that Peter left). Because of this, (22b) can be true even if, for no boy x , the presupposition of $\lceil \text{Ann cares that } x \text{ left} \rceil$ is satisfied, leading to the violation of C-DISTRIBUTIVITY.

On the other hand, the lexical entry in (23) predicts that *care* satisfies P-TO-Q ENTAILMENT. This is so because, if there is an answer p to Q that satisfies the presupposition and the assertion of $\lceil x \text{ cares } p \rceil$ according to the analysis in (23), it follows that the presupposition and the assertion of $\lceil x \text{ cares } Q \rceil$ according to the analysis in (23) are also satisfied.⁵

4.3 Daroo

Recall that the Japanese particle *daroo* means ‘think’ when it takes a declarative prejacent and something similar to ‘wonder’ when it takes an interrogative prejacent. Hara (2018) and Uegaki & Roelofsen (2018) analyze *daroo* as follows, modulo some details that are irrelevant here:

$$(24) \quad \llbracket \text{daroo} \rrbracket^w = \lambda Q_{\langle st, t \rangle} \cdot \text{INQ}_{sp}^w \subseteq Q \quad (sp: \text{ the speaker})$$

Here, INQ_{sp}^w is the inquisitive state of the speaker in w , also employed in the analysis of *wonder* in (16). That is, it is the set of subsets of DOX_{sp}^w in which the issues that the speaker entertains in w are resolved. Thus, according to (24), φ -*daroo* means that the speaker would like to reach a doxastic state which resolves the issue expressed by φ . We first motivate this analysis of *daroo* empirically, and then move on to show that it satisfies P-TO-Q ENTAILMENT.

(24) captures the fact that *p-daroo*, with a declarative prejacent p , simply means ‘the speaker believes p ’ since $\bigcup \text{INQ}_{sp}^w = \text{DOX}_{sp}^w$ (see Uegaki & Roelofsen 2018):

$$(25) \quad \llbracket p \text{ daroo} \rrbracket^w = 1 \quad \text{iff} \quad \text{INQ}_{sp}^w \subseteq \{p\}^\downarrow \quad \text{iff} \quad \text{DOX}_{sp}^w \subseteq p$$

⁵ More formally, for any term x and any exhaustivity-neutral Q , the following holds: Suppose there is a $p \in \text{alt}(Q)$ s.t. $\llbracket \text{care} \rrbracket^w(\{p\}^\downarrow)(x)$. Given (23), this is true iff (i) $\text{DOX}_x^w \subseteq p$ and (ii) $\text{BOU}_x^w \subseteq p \vee \text{BOU}_x^w \cap p = \emptyset$. Now, because $p \in \text{alt}(Q)$, (i) entails the presupposition of $\llbracket \text{care} \rrbracket^w(Q)(x)$, i.e., $\text{DOX}_x^w \subseteq \bigcup Q$. On the other hand, (ii) entails the assertion of $\llbracket \text{care} \rrbracket^w(Q)(x)$, i.e., $\exists p \in \text{alt}(Q) : \text{BOU}_x^w \subseteq p \vee \text{BOU}_x^w \cap p = \emptyset$. Hence, (i) and (ii) together entail $\llbracket \text{care} \rrbracket^w(Q)(x)$.

On the other hand, with an interrogative prejacent Q , Q -*daroo* is predicted to mean that the speaker entertains the issue represented by Q :

$$(26) \quad \llbracket Q \text{ daroo} \rrbracket^w = 1 \quad \text{iff} \quad \text{INQ}_{sp}^w \subseteq Q$$

This is an empirically accurate analysis of the interpretations of *daroo*.

The entry in (24) satisfies P-TO-Q ENTAILMENT as formulated in (21). This is so because, for any exhaustivity-neutral Q , if there is an answer p to Q such that $\lceil p\text{-daroo} \rceil$ is true, it follows that $\lceil Q\text{-daroo} \rceil$ is also true.⁶

We have stated that *daroo* roughly means ‘wonder’ when it takes an interrogative complement. However, the analysis in (24) is crucially different from that of *wonder-Q* according to the semantics we have given above in (16), repeated here:

$$(27) \quad \llbracket \text{wonder } Q \rrbracket^w = \lambda x. \text{DOX}_x^w \notin Q \wedge \text{INQ}_x^w \subseteq Q$$

The crucial difference is that *daroo* lacks the ignorance component, $\text{DOX}_x^w \notin Q$, which is part of the semantics of *wonder*. The lack of the ignorance component in the semantics of *daroo* is motivated by the following kind of examples:

- (28) Huji-santyo-de-wa mizu-wa nando-de huttoo-suru daroo-ka.
 Mt.Fuji-top-LOC-TOP water-TOP what.degree-in boil-do DAROO-Q
 Huji-santyo-de-wa kiatsu-ga tijoo-no sanbunnoni
 Mt.Fuji-top-LOC-TOP air.pressure-NOM ground.level-GEN two-thirds
 kurai nanode, mizu-wa yaku 87.7 do de huttoo-suru.
 about because water-TOP about 87.7 °C at boil-do
 ‘At what temperature does water boil at the top of Mt. Fuji? Since the air pressure there is about 2/3 of the ground level, it boils at about 87.7°C.’

Here, the author/speaker uses Q -*daroo* to introduce the question Q as a topic, which she in fact knows the answer to. This suggests that Q -*daroo* does not semantically entail the speaker’s ignorance about Q .⁷ This is in contrast to the behavior of *wonder*, which is infelicitous in a similar context:

- (29) #I wonder at what temperature water boils at the top of Mt. Fuji. Since the air pressure there is about 2/3 of the ground level, it boils at about 87.7°C.

The lack of the ignorance component furthermore captures the fact that *daroo* is responsive, i.e., compatible with both declarative and interrogative prejacent. If

6 More formally: suppose there is a $p \in \text{alt}(Q)$ s.t. $\llbracket \text{daroo} \rrbracket^w(\{p\}^\downarrow)$. Then, by (24), we have that $\text{INQ}_{sp}^w \subseteq \{p\}^\downarrow$. This entails $\text{INQ}_{sp}^w \subseteq Q$ since $p \in \text{alt}(Q)$. Hence, $\llbracket \text{daroo} \rrbracket^w(\{p\}^\downarrow)$ entails $\llbracket \text{daroo} \rrbracket^w(Q)$.

7 Although Q -*daroo* may pragmatically implicate ignorance as a result of competition with p -*daroo*, where p is a specific answer of Q , as suggested in Uegaki & Roelofsen 2018.

daroo carried the ignorance component in its semantics, we would expect it to be rogative just like *wonder*, i.e., be incompatible with declarative prejacent due to the predicted contradiction in meaning.

4.4 *Mõtlema*

As discussed above, Roberts (2018) gives the following empirical description of the behavior of *mõtlema*.

- (30) When φ is declarative, $\lceil x \text{ mõtlema } \varphi \rceil$ means that (a) x believes that φ is true; or that (b) x believes not- φ but imagines what the world would be like if φ were true.
- (31) When φ is interrogative, $\lceil x \text{ mõtlema } \varphi \rceil$ means that (a) x wonders what the answer to φ is; or (b) for some answer p to φ , x believes not- p but imagines what the world would be like if p were true.

Staying close to this basic empirical description by Roberts (2018), we assume that *mõtlema* has two interpretations: On its ‘daroo’ interpretation, it says that the subject ‘entertains’ the issue expressed by the complement (this yields the ‘believe’ reading when the complement is declarative and the ‘wonder’ reading when the complement is interrogative). On its ‘imagine’ interpretation, it says that there is an answer to the issue expressed by the complement such that the subject believes its negation and imagines what the world would be like if it were true. This is reflected in the disjunctive lexical entry below, where IMG_x^w is the set of worlds that are compatible with what x imagines in w .⁸

⁸ Roberts (2018) proposes an analysis of *mõtlema* that aims at unifying all its readings by making reference to what he calls the CONTEMPLATION STATE of the subject. The contemplation state of an agent is defined as a set of questions (each modelled as a partition of a set of contextually relevant possible worlds). These questions are ones that are ‘under active consideration’ by the agent. The semantics of *mõtlema* is then proposed to be as follows:

- (i) $\llbracket \text{mõtlema} \rrbracket^w = \lambda Q \lambda x. Q \in \text{CONT}_x^w$ (where CONT_x^w : the contemplation state of x in w)

Roberts assumes a semantics of clausal complements similar to that of inquisitive semantics, but without downward closure.

While this proposal may be a possible starting point, we believe that it would have to be further articulated in order to make clear predictions. In particular, what needs further elaboration is what it means for a (possibly singleton) set of propositions to be ‘under active consideration’ by an agent. For instance, if a certain question Q is in the contemplation state of an agent x , does it follow that every sub-question of Q is also in x ’s contemplation set? Or that every singleton subset of Q (each corresponding to an exhaustive resolution) is in x ’s contemplation set? Or, perhaps, that at least two of these singleton subsets are (in case Q is not a singleton to begin with)? For the account to make clear predictions, these questions need to be resolved. This would be an interesting project to further

$$(32) \quad \llbracket \text{m\ddot{o}tlema} \rrbracket^w = \lambda Q_{\langle st,t \rangle} \lambda x_e. \overbrace{\text{INQ}_x^w \subseteq Q}^{\text{'daroo'}} \vee \overbrace{\exists p \in \text{alt}(Q) : \text{DOX}_x^w \subseteq \bar{p} \wedge \text{IMG}_x^w \subseteq p}^{\text{'imagine'}}$$

Having fixed this semantic analysis of *m\ddot{o}tlema*, we can now ask whether it is P-TO-Q ENTAILING. Suppose that Q is an exhaustivity-neutral question and p an answer to Q such that $\lceil x \text{ m\ddot{o}tlema } p \rceil$ is true. On the ‘daroo’ reading, this means that $\text{INQ}_x^w \subseteq \{p\}^\downarrow$ (x believes p). But then $\lceil x \text{ m\ddot{o}tlema } Q \rceil$ is true as well on the daroo reading. On the ‘imagine’ reading, it means that x does not believe p but imagines what the world would be like if p were the case. Then it follows that $\lceil x \text{ m\ddot{o}tlema } Q \rceil$ is true as well on the imagine reading. So, indeed, *m\ddot{o}tlema* is P-TO-Q ENTAILING.

4.5 Wonder

Finally, *wonder* as analyzed below, repeated from §3.3 above, satisfies P-TO-Q ENTAILMENT as well.

$$(33) \quad \llbracket \text{wonder} \rrbracket^w = \lambda Q_{\langle st,t \rangle} \lambda x_e. \text{DOX}_x^w \not\subseteq Q \wedge \text{INQ}_x^w \subseteq Q$$

This is so since $\llbracket \text{wonder} \rrbracket^w(\{p\}^\downarrow)(x)$ is false for any x and p . This means that P-TO-Q ENTAILMENT is trivially satisfied.

4.6 Non-attested predicates

We have seen that P-TO-Q ENTAILMENT *rules in* the predicates that pose challenges for previously proposed constraints. At the same time, it is still significant in that it *rules out* many conceivable but non-attested predicates.

Consider first the predicate in (34), meaning ‘consider all possibilities open’:

$$(34) \quad \llbracket \text{all-open} \rrbracket^w = \lambda Q \lambda x. \forall p \in \text{alt}(Q) : \text{DOX}_x^w \cap p \neq \emptyset$$

This predicate violates P-TO-Q ENTAILMENT, because it is possible for DOX_x^w to be compatible with some $p \in \text{alt}(Q)$ without being compatible with all $p \in \text{alt}(Q)$. To our knowledge, this prediction is correct, i.e., no language lexicalizes (34). More generally, this seems true for all predicates that quantify *universally* over the alternatives in the denotation of their complement. This (*prima facie* unexpected) general restriction is predicted by P-TO-Q ENTAILMENT.

Next, consider the following fictitious predicate from Steinert-Threlkeld 2020, where $\text{info}(Q) := \bigcup Q$ denotes the informative content of Q .

pursue, but we do not see at this point how it could be done in such a way that the reported readings could be captured in a fully uniform way. Therefore, for now, we specify a semantics for *m\ddot{o}tlema* which, while capturing all the reported readings, is not fully uniform.

$$(35) \quad \llbracket \text{wondows} \rrbracket^w = \lambda Q \lambda x. \left(\begin{array}{l} w \in \text{DOX}_x^w \wedge \text{DOX}_x^w \subseteq \text{info}(Q) \wedge \\ \forall p \in \text{alt}(Q) : \text{DOX}_x^w \cap p \neq \emptyset \end{array} \right)$$

Steinert-Threlkeld (2020) describes this predicate as roughly meaning *know* when taking a declarative complement, while meaning *be uncertain* when taking an interrogative complement. The first and the second requirement posed by *wondows* are that x 's doxastic state does not rule out the actual world w and that it supports the informative content of Q . The third requirement corresponds to that posed by *all-open*. *wondows* is therefore ruled out by P-TO-Q ENTAILMENT on similar grounds as *all-open*: a belief state may, besides being truthful and supporting $\text{info}(Q)$, be compatible with some $p \in \text{alt}(Q)$ without being compatible with all $p \in \text{alt}(Q)$.

We now turn to *shknow*, the fictitious predicate considered by Spector & Egré (2015). One way to formulate the lexical entry of *shknow* is as follows:

$$(36) \quad \llbracket \text{shknow} \rrbracket^w = \lambda Q \lambda x. \left(\begin{array}{l} w \in \text{DOX}_x^w \wedge \text{DOX}_x^w \subseteq \text{info}(Q) \wedge \\ \forall p \in \text{alt}(Q) : \text{DOX}_x^w \cap p \neq \emptyset \wedge \text{INQ}_x^w \subseteq Q \end{array} \right)$$

Note that the first three requirements are those of *wondows* (encoding knowledge when combined with a declarative complement and uncertainty when combined with an interrogative complement). The fourth requirement adds an essential component of the meaning of *wonder*, namely that the subject wants to reach an epistemic state in which the issue expressed by the complement is resolved. This predicate also violates P-TO-Q ENTAILMENT, still essentially because of the requirement stemming from *all-open*.

We should note that the *all-open* requirement forces a very strong level of ignorance (compatibility with *all* alternatives). Intuitively, it is possible for x to wonder, say, who won the race, even if x can already rule out some possible winners (see Cremers, Roelofsen & Uegaki 2019 for relevant experimental results). Given that *shknow* is intended to mean *wonder* when taking an interrogative complement, one may want to adapt the entry in (36), so as to make room for a weaker ignorance requirement. One way to do so is as in (37).⁹

$$(37) \quad \llbracket \text{shknow} \rrbracket^w = \lambda Q \lambda x. \left(\begin{array}{l} (|\text{alt}(Q)|=1 \wedge \text{DOX}_x^w \in Q) \vee \\ (|\text{alt}(Q)| \neq 1 \wedge \boxed{\text{DOX}_x^w \notin Q} \wedge \text{INQ}_x^w \subseteq Q) \end{array} \right)$$

Under this analysis, *shknow* still violates P-TO-Q ENTAILMENT. This is because, for

⁹ Note that the entry in (37) makes explicit reference to the cardinality of $\text{alt}(Q)$. As far as we can see, it is not possible to achieve the same result without making such reference to $|\text{alt}(Q)|$. We suspect that there may be a universal constraint on the denotation of clause-embedding predicates which prohibits such irreducible reference to $|\text{alt}(Q)|$, but we leave open here how such a constraint should be formulated exactly and how it would be tested.

any Q and any $p \in \text{alt}(Q)$, if $\llbracket \text{shknow} \rrbracket^w(\{p\}^\downarrow)(x)$ is true, then $\llbracket \text{shknow} \rrbracket^w(Q)(x)$ is *false* due to the weak ignorance requirement that applies when it takes an interrogative complement (shown within a rectangle).

Finally, let us consider the fictitious predicate *knopinion*, discussed in Steinert-Threlkeld 2020. Intuitively, this predicate means *know* when taking an interrogative complement and *be opinionated* when taking a declarative complement. Steinert-Threlkeld (2020) gives the following lexical entry:

$$(38) \quad \llbracket \text{knopinion} \rrbracket^w = \lambda Q \lambda x. w \in \text{DOX}_x^w \wedge (\text{DOX}_x^w \in Q \vee \text{DOX}_x^w \in \neg Q)$$

where $\neg Q := \{p \mid \forall q \in Q : q \cap p = \emptyset\}$

To see that this predicate does not satisfy P-TO-Q ENTAILMENT, suppose that Mary truly believes that Bill did *not* win the race but doesn't know who did. Then, (39) is true while (40) is false.

(39) Mary knopinions that Bill won the race. true

(40) Mary knopinions which athlete won the race. false

So we have found a subject x , an exhaustivity-neutral Q and an answer p to Q such that $\lceil x \text{ knopinions } p \rceil$ is true while $\lceil x \text{ knopinions } Q \rceil$ is false. This means that P-TO-Q ENTAILMENT is violated.

5 Potential counterexamples

So far, we have considered attested and non-attested predicates for which P-TO-Q ENTAILMENT makes correct predictions. In this section, we highlight some potential counterexamples to our proposal from Buryat, Turkish, Tagalog and English.

5.1 Buryat *hanaxa* and Turkish *bil*

Bondarenko (2019) investigates the clause-embedding predicate *hanaxa* ‘think/recall’ in Buryat. When combining with a declarative complement, *hanaxa* is non-veridical, as illustrated in (41) (example (4) in Bondarenko 2019).

(41) dugar mi:səi zagaha əd-jə: gəžə han-a: xarin mi:sgəi zagaha
 Dugar cat.NOM fish eat-PST comp think-PST but cat fish
 ədj-ə:-güj
 eat-PST-NEG
 ‘Dugar thought that a cat ate fish, but the cat didn’t eat fish.’

But when combined with an interrogative complement, the predicate is veridical, as

illustrated in (42) (example (118) in Bondarenko 2019).

- (42) bi badma tamxi tata-dag gü gəʒə hana-na-b
 1SG.NOM Badma.NOM tobacco smoke-HAB Q COMP think-PRS-1SG
 ‘I am recalling (the true answer to the question) whether Badma smokes.’

This sentence does not just convey that the speaker recalls *some* answer to the question, but that she recalls the *true* answer. This means that (43a) can be true without (43b) being true, suggesting that *hanaxa* violates P-TO-Q ENTAILMENT.

- (43) a. Mary hanaxa that Bill left. b. Mary hanaxa whether Bill left.

However, Bondarenko (2019) argues that *hanaxa* combines with declarative and interrogative complements in different ways. Specifically, interrogative complements fill an argument slot of the predicate, while declarative complements function as modifications of the event description that the predicate is part of (Kratzer 2006; Moulton 2009). Under this account, the empirical observations made so far are compatible with the assumption that *hanaxa* satisfies P-TO-Q ENTAILMENT (as it reduces to the cases of inquisitive predicates, i.e., those predicates that cannot take a declarative clause as their argument).

Özyıldız (2019) reports that the predicate *bil* in Turkish has a profile similar to *hanaxa* in Buryat. A more comprehensive investigation would be needed in order to fully understand how these predicates interact with interrogative complements and whether they constitute counterexample to P-TO-Q ENTAILMENT.

5.2 Tagalog *magtaka*

The Tagalog predicate *magtaka* is translated as *surprise* when it takes a declarative complement, and as *wonder* when it takes an interrogative complement.¹⁰

- (44) Nagtaka si Sara na dumating si Maria.
 magtaka.PFV NOM Sara that arrived.AV NOM Maria
 ‘Sara was surprised that Maria arrived.’
- (45) Nagtaka si Sara kung sino ang dumating.
 magtaka.PFV NOM Sara if who NOM arrived.AV
 ‘Sara wondered who arrived.’

A preliminary investigation suggests that (44) does not imply (45). This would mean that the predicate violates P-TO-Q ENTAILMENT. We must leave a more in-depth

¹⁰ We are grateful to Henrison Hsieh and Florinda Palma Gil for discussing this case with us and providing native speaker judgments.

investigation of this case for future work.

5.3 *Explain*

Pietroski (2000) and Elliott (2016) argue that when *explain* takes a declarative complement, this complement does not describe the ‘explanandum’—what is being explained—but rather the content of the explanation, i.e., the ‘explanans’. See (46):

- (46) a. Bill asked Mary why she wanted to leave.
b. Mary explained that she wasn’t feeling well.

(46b) does not report that Mary was explaining the fact that she wasn’t feeling well. Rather, she explained why she wanted to leave. The content of the explanation was that she wanted to leave because she wasn’t feeling well. By contrast, if *explain* takes an interrogative complement, this complement always describes the explanandum rather than the content of the explanation.

- (47) Mary explained how she was feeling.

This sentence reports that Mary gave an explanation of her feelings, not that she described her feelings in order to explain something else, e.g., why she wanted to leave. Based on these examples, it may seem that *explain* violates P-TO-Q ENTAILMENT. After all, (46b) does not entail (47). The former conveys that Mary explained why she wanted to leave, namely because she wasn’t feeling well. But this does not entail that she gave an explanation of her feelings.

However, before concluding that *explain* violates P-TO-Q ENTAILMENT, we first have to better understand how the verb combines with declarative and interrogative complements. The discussion in Elliott 2016 is relevant here, although it does not contrast declarative complements with interrogative ones, but rather declarative complements with DP arguments, as in (48).

- (48) Mary explained the fact that she wasn’t feeling well.

In this sentence, the DP argument of the verb describes the explanandum, just like in (47), rather than the content of the explanation. To derive the contrast between cases like (46b) and (48), Elliott (2016) suggests that declarative complements are modifiers of an event description, while DPs are thematic arguments. If an account of the contrast between (46b) and (48) on the bases of such a combinatorial difference is on the right track, then it may be extended to capture the contrast between (46b) and (47) as well, in a way similar to how declarative and interrogative complements of *hanaxa* are treated in Bondarenko 2019. We would have to assume that interrogative complements, like DPs, fill an argument slot of the verb. Whatever fills this argument

	<i>*shknow</i>	<i>*knopinion</i>	<i>care</i>	<i>mõtlema</i>	<i>daroo</i>	<i>wonder</i>
VERIDICALITY UNIFORMITY	✓	✓	✗	✓	✓	NA
C-DISTRIBUTIVITY	✓	✓	✗	✗	✗	✗
STRAWSON C-DISTRIBUTIVITY	✓	✓	✓	✗	✗	✗
P-TO-Q ENTAILMENT	✓	✓	✓	✓	✓	✓

Table 2 Summary of the predictions of the constraints considered in the paper

slot always describes the explanandum, not the content of the explanation. On such an account, the fact that (46b) fails to entail (47) does not imply that *explain* violates P-TO-Q ENTAILMENT. In (46b) the predicate does not take the declarative clause as its argument. Only clauses that describe the explanandum (rather than the explanans) fill the argument slot of the predicate.¹¹

6 Conclusion

We have discussed a number of issues for recently proposed constraints on the possible denotations of clause-embedding predicates. We have also proposed a new constraint, P-TO-Q ENTAILMENT, which overcomes these issues. A summary of the predictions made by the constraints discussed in this paper is given in Table 2.

Much work remains to be done, however. In particular, we have highlighted a number of potential counterexamples which need to be investigated in further detail and might require further revisions of the constraint we have proposed.

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¹¹ The situation may be slightly more involved. While Pietroski (2000) and Elliott (2016) assume that declarative complements *always* describe the content of the explanation, it seems to us that it is in fact also possible for them to describe the explanandum. This is illustrated in (i).

- (i) Now I will explain that this algorithm works whenever $x < 5$, but not when $x \geq 5$.

The declarative complement in (i) is an answer to ‘When does the algorithm work?’ So, in order to check whether *explain* satisfies P-TO-Q ENTAILMENT, we should verify that (i) entail (ii).

- (ii) I will explain when this algorithm works.

The entailment indeed goes through, which is compatible with the assumption that *explain* satisfies P-TO-Q ENTAILMENT. We leave a more elaborate analysis of *explain* for future work.

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