Towards Referential Transparent Annotations of Quantified Noun Phrases

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Abstract

Using recent developments in count noun quantification, namely *Referential Transparency Theory* (RTT), the basic structure for annotating quantification in the nominal domain according to RTT is presented. The paper discusses core ideas of RTT, derives the abstract annotation syntax, and exemplifies annotations of quantified noun phrases partly in comparison to QuantML.

1 Introduction

The collection of interoperable semantic annotation standards known as the *Semantic Annotation Framework* (SemAF) includes an annotation schema for the annotation of quantification phenomena called QuantML (Bunt, 2019b; Bunt et al., 2022). QuantML draws on work in formal and computational semantics, in particular Generalized Quantifier Theory (Barwise and Cooper, 1981), Discourse Representation Theory (Kamp and Reyle, 1993), and neo-Davidsonian event semantics (Davidson, 1967; Parsons, 1990). It aims at a considerable if not complete coverage of natural language quantification.

With respect to quantified noun phrases (QNPs) – that is, noun phrases which involve a quantifier word – an alternative to Generalized Quantifier Theory (GQT) has recently been developed in terms of *Referential Transparency Theory* (RTT; Lücking and Ginzburg, 2022).[1] RTT draws its main motivation from data of natural language use as observed in dialogical interactions, where higher-order denotations postulated by GQT do not seem to be confirmed. Hence, RTT pursues a witness-based approach to quantification, which arguably simplifies the representation of quantification phenomena. QuantRTT aims at an annotation schema which makes the RTT approach available for annotation.

The paper is organized as follows. Section 2 introduces the key ideas of RTT that are needed to understand the annotation approach outlined in section 3. The interpretation of QuantRTT annotations in the RTT framework is briefly covered in section 4. Some phenomena outside the current scope of QuantRTT are discussed in section 5. We conclude in section 6.

2 Brief Primer into RTT

Perhaps the most consequential feature of RTT is that quantification with quantificational determiners and nouns happens entirely within the noun phrase. In other words, a QNP such as *many goldfish* is interpreted without reference to a so-called scope set (the property donated by the verb phrase in GQT). RTT makes crucial use of the fact that QNP contents seem to be readily structured entities, as is revealed by their anaphoric potential. Consider (1): The initial sentence introduces a QNP (*few environmentalists*). The few environmentalists that actually came to the rally – the *reference set* (refset) – are picked up by the plural pronoun in (1a). However, two additional sets become accessible: the "refset environmentalists" seem to be drawn from a larger group of environmentalists – the *maximal set* (max set) –, which is picked out by the plural pronoun phrase in (1b). The plural pronoun in (1c), finally, picks out those environmentalists that did *not* came to the rally: the *complement set* (compset).[2]

(1) Only few environmentalists came to the rally.

a. But they raised their placards defiantly.

[1] "Transparency" here – a feature of the representation of noun phrase contents – is not to be confused with transparency of QuantML, where it refers to the instantiation of a metamodel (Bunt et al., 2022, §4.3).

[2] The examples in (1) are constructed for the sake of brevity but follow the pattern of corpus examples of maxset/refset/compset anaphora; see, e.g., Del Negro (2020).

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b. Although they all received an invitation.

c. They went to a football game instead.

Note that compset anaphora is only licensed under certain conditions (see, e.g., Nouwen, 2003). RTT offers a *horror vacui*-based explanation here, drawing on empty refsets (Lücking and Ginzburg, 2022, §4.3) – see (4) below.

Assuming that the "QNP anatomy" (a phrase we owe to Cooper, 2013) indeed hosts a set triplet, RTT develops the following QNP structure:

(2)
$$\left[\begin{array}{ll}\text{q-params}: & \left[\begin{array}{ll}\text{refset} & : \textit{Set(Ind)} \\ \text{compset} & : \textit{Set(Ind)} \\ \text{maxset} & : \textit{Set(Ind)} \\ \text{c1} & : \overrightarrow{\textit{PType}}(\text{maxset}) \\ \text{c2} & : \text{union(maxset,refset,compset)}\end{array}\right] \\ \text{q-cond} & : \textit{Rel}(|\text{q-params.refset}|, |\text{q-params.compset}|) \\ \text{q-persp} & : \text{refset} = \emptyset \vee \text{refset} \neq \emptyset \vee \text{ none}\end{array}\right]$$

RTT is formulated within a type theory with records (Cooper and Ginzburg, 2015; Cooper, 2023). The arrow indicates a plural predicate type (*PType*), that is, a predicate that expects a set-valued argument. Condition c2 simply states that refset and compset add up to the maxset. Obviously, the structure in (2) provides suitable antecedents for the above-given range of anaphora. The value of condition c1 is donated by the predicate type of the head noun (e.g., *environmentalist*, *goldfish*), which is distributed over all maxset members (and thereby over refset and compset). The quantificational workhorse is the quantifier condition "q-cond": it captures what can be called the descriptive meaning of a QNP. For instance, the q-cond of *many* states that the refset is larger than the compset (|refset| > |compset|). The quantificational condition of *all* has it that the compset is empty, or equivalently, that refset and maxset coincide. Hence, q-cond not only expresses NP-internal quantification (i.e., quantification without a scope set from the VP), it also implements quantifiers as "sieves", a metaphor due to Barwise and Cooper (1981). This is achieved since RTT is denotationally underpinned by sets of ordered set bipartitions, mathematical structures which correspond to inversely coupled pairs of the elements of the power set of the head noun's denotation.

(3) **Ordered set bipartition.** An ordered set bipartition b of a set s is a pair of disjoint subsets of s including the empty set such that the union of these subsets is s. We refer to the set of all possible ordered set bipartitions of a set s as the *set of ordered set bipartitions*.

For example, let the denotation $[\downarrow]$ of the type *Bicycle* be a set of three bicycles: $[\downarrow \text{Bicycle}] = \{🚲, 🚲, 🚲\}$. Then function p returns the set of ordered set bipartitions:

(4)
$$\begin{aligned} p([\downarrow \text{Bicycle}]) = \{ & \langle \emptyset, \{🚲, 🚲, 🚲\}\rangle, \\ & \langle \{🚲\}, \{🚲, 🚲\}\rangle, \\ & \langle \{🚲\}, \{🚲, 🚲\}\rangle, \\ & \langle \{🚲\}, \{🚲, 🚲\}\rangle, \\ & \langle \{🚲, 🚲\}, \{🚲\}\rangle, \\ & \langle \{🚲, 🚲\}, \{🚲\}\rangle, \\ & \langle \{🚲, 🚲\}, \{🚲\}\rangle, \\ & \langle \{🚲, 🚲, 🚲\}, \emptyset\rangle\} \end{aligned}$$

Each ordered set bipartition in the set of ordered bipartitions is structured in the form ⟨refset, compset⟩. Accordingly, the last ordered set bipartition in (4), the one with an empty compset, is the denotation of *every bicycle* in the sample universe. The first bipartition, the one with an empty refset, corresponds to *no*-type NPs. Those bipartitions which have more elements in the refset than in the compset are the denotations of *many*-type NPs. Note that the (hypothesized) semantic universal of *conservativity* (Keenan and Stavi, 1986) ("lives on" in the terminology of Barwise and Cooper 1981) is an immediate consequence.

Feature q-persp in (2) indicates whether the bipartition with the empty refset is part of a QNP's denotation; if so, its feature value is "refset = ∅"; otherwise "refset ≠ ∅". NPs for which q-persp is not applicable – such as proper names – have no q-persp value ("none"). Thus, the q-persp value is denotationally well-founded and regiments compset anaphora: the compset is available as antecedent only if "q-persp : refset = ∅".

Any NP-internal approach to quantification needs to say something about how a QNP combines with a verb phrase (VP) into a sentence. RTT – in contrast to GQT – adopts the standard (and intuitively pleasing) notion of predication: the verb predicates of its arguments. To be more precise: VP content applies to the refsets of its arguments. That is, the meaning of a sentence like *Every dog barks* is compositionally derived as illustrated in (5), abbreviated to the necessary degree (the pair of a situation and a situation type is an *Austinian* *proposition* (Ginzburg, 2012); label “q-params” is abbreviated “q-p” in some paths here and in the following for reasons of space):

(5)
$$\left[\begin{array}{l} \text{q-params} : \left[\begin{array}{ll}\text{refset} : \textit{Set}(\textit{Ind})\\ \text{c1} & : \overrightarrow{\textit{dog}}(\text{refset})\end{array}\right] \\ \text{cont} = \left[\begin{array}{l}\text{sit=s0} : \textit{Rec}\\ \text{sit-type=}\left[\begin{array}{l}\text{q-cond : compset=} \emptyset\\ \text{nucl} : \overrightarrow{\textit{bark}}(\text{q-p.refset})\\ \text{anti-nucl} : \neg\overrightarrow{\textit{bark}}(\text{q-p.compset})\end{array}\right]\end{array}\right]\end{array}\right]$$

Note that (5) involves “anti-predication” of the compset. Postulating multi-dimensional denotations is not uncommon in semantics, Rooth (2016), for instance, argues for a related move.

Since a plural type takes a set of individuals as argument, the question arises on how exactly the predicate relates to the members of the set. The predicate *bark* in (5) obviously distributes to every single dog from the refset. This is distinct from collective predicates like *gather*, which apply to sets of individuals, and predicates like *carry-a-piano*, which, when asserted of a set of people, can be understood in a distributive or a collective way, and anything in between (Scha, 1984). Spelling out the details of distributivity is a bit involved (see Lücking, 2022, Sec. 2.5), therefore QuantRTT offers simple notational abbreviations, following the subtyping relation in (6):

(6)
$\overrightarrow{\textit{PType}}$
partial distrib./inside coll.
fully distrib. outside coll.

The general plural type imposes no restriction onto its interpretation, whereas fully distributive and outside collective ones require what their names suggest. The types in the middle express that a plural predicate applies to individuals and to any subgroups of the refset (this is RTT’s counterpart to *covers*, lattices of subsets under set inclusion). Since these substructures can be seen from the perspective of either distributivity (in terms of partiality) or collectivity (in terms of inside collections), there are two possible ways to name these subtypes.

Let us briefly illustrate matters by means of a simple example: *Every dog chased a cat.* This sentence can be used to describe situations of different kinds, namely a situation where (i) a bunch of dogs together chased a cat (outside collective), (ii) each dog from the bunch chased a different cat (fully distributive), or (iii) some dogs chased in teams (i.e., there is more than one cat but the number of cats is less than the number of dogs).

How does this exposition fit to so-called narrow and wide scope readings (∀∃ vs. ∃∀)? It does not, since scope is replaced by *dependent* interpretations of QNPs (Zeevat, 2018; Ginzburg, 2012), which apply *in situ* and introduce a function. The relevant content parts for the *every-dog-chased-a-cat* example are shown in (7). The subject QNP introduces a refset (and a suitable q-cond), as usual. The object QNP introduces a function f which associates an individual x with a cat z. The nucleus distributively applies the predicate and the function to the subject’s refset, which provides entities x (dogs in our example) as input for f, which in turn returns a cat each (i.e., an individual of type *cat*).[3]

(7)
$$\left[\begin{array}{l} \text{q-params} : \left[\begin{array}{l}\text{refset} : \textit{Set}(\textit{Ind})\\ \text{c1} : \overset{\text{dist}}{\overrightarrow{\text{dog}}}(\text{refset})\\ \text{f} : ([\text{x} : \textit{Ind}])\left[\begin{array}{l}\text{z=f(x)} : \textit{Ind}\\ \text{c0} : \text{cat(z)}\end{array}\right]\end{array}\right] \\ \text{nucl} : \overset{\text{dist}}{\overrightarrow{\text{chase}}}(\text{q-p.refset,f(q-p.refset)})\\ \text{anti-nucl} : \neg\overset{\text{dist}}{\overrightarrow{\text{chase}}}(\text{q-p.compset,f(q-p.compset)})\end{array}\right]$$

The representational format of RTT – albeit presumably uncommon to most readers – is arguably more transparent than equivalent formulæ of second order predicate logic. Moreover, there is a systematic distinction between *quantification* (q-params) and *predication* (nucl). For this reason, the domain of markables of QuantRTT is more restricted than that of QuantML.

This leaves a final and potentially intricate issue: definiteness. Coming from a dialogical point of view, RTT employs a “referential bookkeeping mechanism”, following HPSG-related work (Ginzburg and Purver, 2012). The crucial idea is that certain nominal expressions are expected to be *witnessed* while others are “quantified away”. This is expressed in terms of two sets of parameters, *dgb-params* and *q-params*. Elements within the dialogue gameboard parameters (dgb-params; a generalization of Kaplanian indices) are expected

[3]Imposing further constraints on f bring about, for instance, interpretations for *same* (f constant) and *different* (f injective) (Lücking, 2022, p. 78).

to be instantiated by an object or a set of objects known to the speaker(s), whereas quantificational parameters (q-params) need not have a specific witness. Note that during dialogical clarification interaction the status of belonging to either dgb-params or q-params can switch.

3 Annotating with QuantRTT

We follow the general approach of QuantML and conceive a markable m and an annotation s as an entity structure $\langle m, s\rangle$. Markables are the strings making up noun phrases. Annotations are derived from the above-introduced QNP anatomy. The relation between two or more entity structures is captured in terms of a link structure. The inventory of QuantRTT looks as follows:

1. *Entities* have the following features, where the corresponding feature values are given after the colon:
   - `q-cond`: `compset=empty` (for *every*, *all*), `refset=empty` (for *no*), potentially negated by "!" [see (13b) below], a condition of the form '`refset` R `compset`', with $R \in \{\leq, <, \ll, =, \geq, >, \gg\}$, or `card=`$n$ ($n \in \mathbb{R}$)[4]
   - `status`: `dgb`, `q` (assigning no value corresponds to "unknown")
   - `ptype`: the predicate of the head noun in question
   - `distrib`: `full`, `part`, `coll` (assigning no value corresponds to "unknown" and allows for any interpretation according to (6))
2. *Links* connect dependent NPs with the NP they depend on *via* the value of the eponymous feature `dep(endent)_on`.

Note that we omit the annotation of q-persp since it is not involved in quantification proper but mainly regiments compset anaphora.

Comparing the inventories of QuantML and QuantRTT, we are aware of the following correspondences ($\sim$):

- `ptype` $\sim$ `pred`
- `maxset` $\sim$ reference domain or context set (Westerståhl, 1985) (the source domain corresponds to a type's denotation "[↓]" and is not part of the annotation)
- `status` $\sim$ `determinacy`
- `distrib=full` $\sim$ `distr=individual`, `distrib=coll` $\sim$ `collective`

The attributes `q-cond` and `involvement` have some functional commonalities, but do not completely correspond to each other, as can be seen, for instance, with NP negation – see (11) and (13b) below. Phenomena such as inverse linking, cover interpretations or group quantification are captured in terms of dependencies (`dep_on`) in combination with `distrib` (cf. Section 2).

All QuantRTT features have direct counterparts in the QNP anatomy. The remainder of this section presents a few examples in order to showcase QuantRTT in action.

A famous example for scope readings is given in (8), discussed by Bunt (2020, p. 4):

(8) Everybody in this room speaks two languages.

The reading where *two languages* is interpreted in the scope of *everybody* (i.e., the reading where there might be different pairs languages for different persons) is annotated in QuantML as follows:

```
<entity xml:id="x1" target="#m1"
↪  involvement="all" definiteness="det"
↪  pred="person"/>
<entity xml:id="x2" target="#m3"
↪  involvement="2" definiteness="indet"
↪  pred="language">
<scoping arg1="#x1" arg2="#x2"
↪  scopeRel="wider"/>
```

The same reading is obtained in QuantRTT by annotating the markable *two languages* as a functional NP which depends on *everybody in this room*:

```
<entity xml:id="x1" target="#m1"
↪  q-cond="compset=empty" status="dgb"
↪  ptype="person"/>
<entity xml:id="x2" target="#m3"
↪  q-cond="card=2" status="q"
↪  ptype="language" dep_on="#x1"
↪  distrib="full">
```

[4]We restrict cardinalities to rational numbers in order to account for examples such *Kim ate 1⅓ pizzas*, pointed out by an anonymous reviewer. Of course, this restriction can be extended to real numbers, if needed.

The value `distrib="full"` indicates that the dependency holds for every single element of the governing NP's denotation. This annotation represents the RTT structures in figures 1 (for *everybody*) and 2 (for *two languages*). The sentential meaning is obtained by relating both structures with the *speaking* relation in such a way that the functional NP is distributionally applied to the refset of the universally quantified NP and is shown in Figure 3. Note, however, that such sentential structures are not part of the scope of markables of QuantRTT, which is confined to the QNP representations in figures 1 and 2, complying to RTT's separation of quantification and verbal predication. The proposition in figure 3 is nonetheless compositionally derived in grammar – HPSG$_{\text{TTR}}$ (Cooper, 2008; Ginzburg, 2012; Lücking et al., 2021) – by using standard constructions such as determiner–noun rules and head–subject rules, and lexical entries for quantifiers like that for *every* in (9) which passes a distributivity marker via its (count) head noun (Beghelli and Stowell, 1997) to the predicating VP, enforcing a (partially) distributive interpretation.

(9)
$$\begin{bmatrix} \text{phon} : \text{/every/} \\ \text{cat} : \begin{bmatrix} \text{head} : \begin{bmatrix} \text{pos=det} & : \textit{PoS} \\ \text{agr} & : \begin{bmatrix} \text{num=sg} : \textit{Num} \end{bmatrix} \\ \text{count=}+ & : \textit{Binary} \end{bmatrix} \\ \text{spec} : \left\langle \begin{bmatrix} \text{cat} : \begin{bmatrix} \text{head} : \begin{bmatrix} \text{pos=n} & : \textit{PoS} \\ \text{distr=}+ & : \textit{Binary} \end{bmatrix} \end{bmatrix} \end{bmatrix} \right\rangle \end{bmatrix} \\ \text{q-params} : \begin{bmatrix} \text{maxset} : \textit{Set(Ind)} \\ \text{refset} : \textit{Set(Ind)} \\ \text{compset} : \textit{Set(Ind)} \\ \text{c1} : \text{union(refset,compset,maxset)} \\ \text{q-cond} : |\text{refset}| = |\text{maxset}| \end{bmatrix} \end{bmatrix}$$

Dependent interpretations also apply to inverse linking arising from prepositional modification as in (10) (Bunt, 2020, p. 7):

(10) Two students from every university [. . .]

```
<entity xml:id="x1" target="#m1"
↪ q-cond="card=2" dep_on="#x2"
↪ distrib="full" ptype="student">
<entity xml:id="x2" target="m3"
↪ q-cond="compset=empty"
↪ ptype="university">
```

Since the sentence does not carry enough information about the status of the discourse referents (dgb vs. q), it is left unspecified.

RTT also offers a compositional treatment of *Not*-type QNPs, such as in (11) (taken from Bunt 2020, p. 7):

(11) Not all the unions accept the proposal.

The basic idea is that *not*, when used as noun phrase negation, inverts the q-cond and q-persp relations of the noun phrase (Lücking and Ginzburg, 2019). (12b) exemplifies the relation of the negated NP from (11) to the positive one in (12a).

(12) a.
$$\begin{bmatrix} \text{refset} & : \textit{Set(Ind)} \\ \text{compset} & : \textit{Set(Ind)} \\ \text{maxset} & : \textit{Set(Ind)} \\ \text{c1} & : \text{union(refset,compset,maxset)} \\ \text{c2} & : \overrightarrow{\text{unions}}\text{(maxset)} \\ \text{q-cond} & : \text{compset} = \emptyset \\ \text{q-persp} & : \text{refset} \neq \emptyset \end{bmatrix}$$

b.
$$\begin{bmatrix} \text{refset} & : \textit{Set(Ind)} \\ \text{compset} & : \textit{Set(Ind)} \\ \text{maxset} & : \textit{Set(Ind)} \\ \text{c1} & : \text{union(refset,compset,maxset)} \\ \text{c2} & : \overrightarrow{\text{unions}}\text{(maxset)} \\ \text{q-cond} & : \text{compset} \neq \emptyset \\ \text{q-persp} & : \text{refset} = \emptyset \end{bmatrix}$$

Note that(12b) correctly accounts for the interaction of *not* and compset anaphora in a compositional manner.

The annotation of (12b) is straightforward (ignoring q-persp, however), using "!" to denote the *not*-operator (thus $!=$ is the same as $\neq$):

(13) a. "all the unions":

```
<entity q-cond="compset=empty">
```

b. "not all the unions":

```
<entity q-cond="compset!=empty">
```

Likewise for other relationships (e.g., $\leq$ of *fewer than* maps to $>$ of *not fewer than*, and so forth).

4 Interpreting Annotations

Since annotations are derived from a QNP anatomy, annotations can be mapped onto either the basic QNP structure in (2) or the functional one in (7) of RTT, as illustrated in figures 1 and 2. Note that in line with RTT's NP-internal approach to nominal quantification and the distinction between quantification and verbal predication, annotations in QuantRTT do not involve verb phrases (i.e., figure 3).

$$
\left[\text{dgb-params} : \begin{bmatrix}
\text{maxset} & : \mathit{Set}(\mathit{Ind}) \\
\text{refset} & : \mathit{Set}(\mathit{Ind}) \\
\text{compset} & : \mathit{Set}(\mathit{Ind}) \\
\text{c2} & : \text{union(refset,compset,maxset)} \\
\text{c1} & : \overset{\text{dist}}{\overrightarrow{\text{person}}}\text{(maxset)} \\
\text{qcond} & : |\text{dgb-params.refset}| = |\text{dgb-params.maxset}|
\end{bmatrix}\right]
$$

Figure 1: Representation of *Everybody*’s dgb-params.

$$
\left[\text{q-params} : \left[\text{f} : ([\text{x} : \mathit{Ind}]) \begin{bmatrix}
\text{refset=f(x)} & : \mathit{Set}(\mathit{Ind}) \\
\text{maxset} & : \mathit{Set}(\mathit{Ind}) \\
\text{compset} & : \mathit{Set}(\mathit{Ind}) \\
\text{c2} & : \text{union(refset,compset,maxset)} \\
\text{c1} & : \overset{\text{dist}}{\overrightarrow{\text{language}}}\text{(maxset)} \\
\text{q-cond} & : |\text{refset}| = 2
\end{bmatrix}\right]\right]
$$

Figure 2: Dependent interpretation of *two languages*’s q-params.

$$
\left[\begin{array}{ll}
\text{dgb-params :} & \begin{bmatrix}
\text{refset-sbj} & : \mathit{Set}(\mathit{Ind}) \\
\text{compset-sbj} & : \mathit{Set}(\mathit{Ind}) \\
\text{maxset-sbj} & : \mathit{Set}(\mathit{Ind}) \\
\text{c0} & : \text{union(refset-sbj,compset-sbj,maxset-sbj)} \\
\text{c1} & : \overrightarrow{\text{person}}\text{(maxset-sbj)} \\
\text{q-cond-sbj} & : |\text{refset-sbj}| = |\text{maxset-sbj}|
\end{bmatrix} \\
\text{cont} \quad = & \begin{bmatrix}
\text{sit = s1 : } \mathit{Rec} \\
\text{sit-type} = \begin{bmatrix}
\text{q-params :} \left[\text{f : ([x : } \mathit{Ind}\text{])} \begin{bmatrix}
\text{refset-obj=f(x) : } \mathit{Set}(\mathit{Ind}) \\
\text{maxset-obj : } \mathit{Set}(\mathit{Ind}) \\
\text{compset-obj : } \mathit{Set}(\mathit{Ind}) \\
\text{c2 : union(refset-obj,compset-obj,maxset-obj)} \\
\text{c1 : } \overset{\text{dist}}{\overrightarrow{\text{language}}}\text{(maxset-obj)} \\
\text{q-cond-obj : } |\text{refset-obj}| = 2
\end{bmatrix}\right] \\
\text{nucl} \quad : \overset{\text{dist}}{\overrightarrow{\text{speak}}}\text{(refset-sbj, f(refset-sbj))} \\
\text{anti-nucl} : \neg\overset{\text{dist}}{\overrightarrow{\text{speak}}}\text{(compset-sbj, f(compset-sbj))}
\end{bmatrix} : \mathit{RecType}
\end{bmatrix} : \mathit{Prop}
\end{array}\right]
$$

Figure 3: Sentence meaning of *Everybody speaks two languages*.

5 Discussion

An anonymous reviewer brought up the following participation example:

(14) Three of the twenty-two students failed the exam.

From the perspective of RTT, (14) involves two cardinality restrictions, one on the refset (viz., "card=3") and one on the maxset ("card=22"). The latter, however, can not yet be expressed in QuantRTT, simply because the annotation inventory (see section 3) lacks a corresponding annotation label. This can easily be fixed in future versions, but will still not capture recursive participant structures as in (15):

(15) Three of the twenty-two students among the forty-eight participants failed the exam.

We are not aware of how (or whether) such examples are to be annotated in QuantML, but we imagine a nested annotation drawing on `involvement` and `sourceDomain`.

The empirical phenomena that underlie the development of RTT involve count nouns. Hence, currently RTT has not much to say about mass nouns and quantification with substances yet, as involved in (16) (Bunt, 2020, p. 6).

(16) The boys drank all the milk in the fridge.

However, given that RTT is formulated in a type theory with records, it seems to be straightforward to follow psychological work (e.g., Rips and Hespos, 2015) and introduce a type *Subst(ance)* alongside *Ind(ividual)*. Given this, it seems that RTT's basic mechanisms can be adapted to substances, in which case the q-cond acts like a sieve on what can be called "refmass" and "compmass":

(17) a. The boys drank most of the milk in the fridge.

b. The boys drank as much of the milk in the fridge as they did not.

On this view, classifiers like *three cups* (*of milk*) induce a type shift from *Subst* to *Ind*.

Furthermore, natural languages provide resources like the English adverbial modifier *twice* to quantify over events (Bunt, 2019b, p. 8):

(18) Two of the children called twice.

Intuitively, (18) says that there have been two calling events by two children (from a certain maxset). RTT has not dealt with temporal or spatial quantification yet. However, a potential direction to account for (18) shall be indicated, drawing on the notion of *string type* (Fernando 2007; Cooper 2023, §2.2). A string type is a concatenation of types. It can be thought of as a flip book and is used for temporally structuring an event into sub-events. Accordingly, potential witnesses of string types are series of situations. Event quantification on this view can be seen as a mechanism of constructing a string of copies (of a number determined by the descriptive meaning of the temporal modifier in question) from a given situation type. Notating the string type '$\overrightarrow{\text{call}}(\text{X})^\frown\overrightarrow{\text{call}}(\text{X})$' simply by a superscript indicating the number of copies (i.e., by '$\overrightarrow{\text{call}}(\text{X})^2$'), (18) is analyzed as follows (omitting details not relevant to the issue at stake):

(19)
$$\left[\begin{array}{l} \text{q-params} : \left[\begin{array}{l}\text{refset} : \mathit{Set}(\mathit{Ind}) \\ \text{c0} : \overrightarrow{\text{child}}(\text{refset})\end{array}\right] \\ \text{cont} = \left[\begin{array}{l} \text{sit} = s_1 s_2 \\ \text{sit-type} = \left[\begin{array}{l} \text{q-cond} : |\text{q-params.refset}| = 2 \\ \text{nucl} : \overrightarrow{\text{call}}(\text{q-params.refset})^2 \end{array}\right]\end{array}\right]\end{array}\right]$$

Note that *sit* now consists of a series of two events, s_1 and s_2.

It is finally noteworthy – since it has been raised as an issue by Bunt (2019b, §7) – that a type theory provides a straightforward analysis of propositional attitude verbs like *believe* or *seek*. Since propositions *are* types (Martin-Löf, 1984), intensional verbs denote a relation between individuals and types, as shown in (20), following Cooper (2005, p. 341).

(20) a. Vic seeks a unicorn.

b.
$$\left[\begin{array}{ll} \text{x} & : \mathit{Ind} \\ \text{c0} & : \text{named(x, "Vic")} \\ \text{p} = \left[\begin{array}{l} \text{y} : \mathit{Ind} \\ \text{c1} : \text{unicorn(y)} \end{array}\right] & : \mathit{RecType} \\ \text{c2} & : \text{seek(x, p)} \end{array}\right]$$

Vic's search will only be successful, if s/he encounters a record (a situation) that contains an individual of the type expressed by the record type p.

6 Conclusion

We presented QuantRTT, an annotation schema for quantified noun phrases based on RTT (Lücking and Ginzburg, 2022). The conceptual underpinnings have been introduced and used to derive the abstract syntax of the annotation schema. We see it as an advantage that QuantRTT brings about a cleaner separation of quantification and verbal predication. Furthermore, given the transparent noun phrase anatomy, QuantRTT arguably lends itself to the integration with anaphora annotation projects (e.g., Loáiciga et al., 2021), contributing to the interoperability of annotations. This could involve to include q-persp in annotations to account for QNPs and compset anaphora in a more systematic way.

A couple of examples comparing QuantML and QuantRTT have been discussed. Although the examples are typeset in the form of concrete XML syntax, there is no standard for QuantRTT yet. To make QuantRTT operable, two further, not mutually exclusive, steps are envisaged. Firstly, QuantRTT can be implemented as an "add-on" to QuantML, for instance as a plug-in as proposed for extensions to dialogue act annotation (Bunt, 2019a). This move will have benefits on both sides: QuantML is connected to RTT and phenomena not yet covered by RTT can be captured by appropriate QuantML resources (although it remains to be seen how well both approaches interact "out of the box"). Note in this context that the intersection of elements in the syntactic inventories of QuantML and QuantRTT is empty, meaning that they can in principle be annotated in parallel.

Secondly, QuantRTT will be incorporated in the TEXTANNOTATOR (Abrami et al., 2021), an annotation suite hosting several annotation tools. This move enables to make use of annotation support from automatic natural language pre-processing tools. Furthermore, due to the graphical user interface, the linking structure of dependent noun phrases can be added in a graphical display by drawing connecting edges.

Of course, QuantRTT will develop as RTT will – a few pointers into potential research directions (e.g., mass nouns and quantificational adverbials) have been given.

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