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FOUR THOUSAND SHIPS PASSED THROUGH THE LOCK: OBJECT-INDUCED MEASURE FUNCTIONS ON EVENTS

1. Introduction

1.1. *Event-Related and Object-Related Readings*

The subject of this paper* is certain peculiar readings of sentences like the following ones:

(1)a. Four thousand ships passed through the lock last year.
b. The library lent out 23,000 books in 1987.
c. Sixty tons of radioactive waste were transported through the lock last year.
d. The dry cleaners cleaned 5.7 million bags of clothing in 1987.
e. 12,000 persons walked through the turnstile yesterday.

Take the first example, (1a) (it is inspired by the basic text of the LiLog project of IBM Germany, which first drew my attention to these sentences). It clearly has two readings. The first one, call it the **object-related** reading, says that there are four thousand ships which passed through the lock last year. The second one, call it the **event-related** reading, says that there were four thousand events of passing through the lock by a ship last year. The object-related reading presupposes the existence of (at least) four thousand ships in the world we are talking about. In the event-related reading, there might be fewer ships in the world. In the limiting case, a single ship passing through the lock about 12 times a day would be sufficient. We find the same ambiguity in the other examples of (1). The library might contain fewer than 23,000 books, there might be less than sixty tons of radioactive waste, there might be less than 5.7 million bags of clothing, and there might be fewer than 12,000 persons – but the sentences (1b–e) could still be true in their event-related readings.

* I had the chance to discuss points related to the subject of this paper with many colleagues. I want to mention especially Lee Baker, Darcy Bruce Berry, Franz Guenthner, Hans Kamp, Peter Lasersohn, Godehard Link, Ede Zimmermann, and two anonymous referees who gave me valuable suggestions.

Linguistics and Philosophy **13**: 487–520, 1990.

1.2. *Two Possible Analyses – And Why They Fail*

Something like the phenomenon of event-related readings was noted by Gupta (1980) and Carlson (1982). However, their solutions apply only to a limited set of examples and presumably cannot be generalized to cover examples like (1).

Gupta's main example is given in (2), an argument which he considers as invalid. Note that this argument is invalid when we take the third sentence, (2c), in its object-related reading.

(2)a. National Airlines served at least two million passengers in 1975.
b. Every passenger is a person.
c. Ergo: National Airlines served at least two million persons in 1975. (invalid)

Gupta's analysis rests on the assumption that the **identity criteria** of *passenger* and *person* differ. For example, Mary, the person who boarded flight NA583 on 5 August 1975, might count as a different passenger from the person who boarded flight NA376 on 11 November 1975, and yet be the same person. Gupta develops a theory in intensional logic in which one can model such different criteria of identity. Basically, common nouns apply not to individuals, but to individual concepts, and two non-identical individual concepts might have the same value at certain reference times without being identical altogether.

Carlson's main example is the noun *batter*. It denotes a role which can apply to different players in a baseball game. Therefore, it can happen that there are far more batters than players in a game of baseball. For example, it is common for a pitcher to face 35 or so batters from a team consisting of only nine members. Carlson analyzes this phenomenon in the ontological framework of Carlson (1978), where he distinguishes, among other things, between objects and **stages** (temporal slices of objects, that is, objects at a certain time). His idea is that a noun like *person* applies to objects, whereas a noun like *batter* applies to stages of objects. As one person can have different stages, it might be the case that a universe contains only nine persons, but 35 batters.

We will not go into the technical parts of Gupta's and Carlson's solutions. It suffices to see that both Gupta and Carlson locate the event-related reading in the meaning of a noun. This might be plausible for sentences with nouns like *passenger*, *batter*, *visitor*, *freight*, *president*, *student*, etc. But we observed the event-related reading also with nouns like *ship*, *book*, *radioactive waste*, *clothing*, *person* in (1), which normally are

not analyzed as applying only to temporal stages of ships, books, radioactive waste, clothing, or persons.

If we want to be heroic and claim that a noun like *ship* is indeed ambiguous and denotes either ships or, say, ship stages, we face a serious problem. In example (1a), we cannot count just any stages of ships, but only those which perform one, and only one, complete pass through the lock. Now, take the ship Eleonore, which has two stages, s_1 and s_2, which passed through the lock. Then also the sum of these two stages should be a stage which passed through the lock. But then our way of counting breaks down: we have suddenly at least three stages, s_1, s_2, and the sum of s_1 and s_2, which passed through the lock. Example (1c), with the mass noun *radioactive waste*, looks even more threatening, if we imagine that the radioactive waste carried to and fro need not always come in the same ships, but might be permutated with different passings.

I conclude that it is the wrong direction to look for an explanation of the event-related readings of (1) in terms of a noun ambiguity. This leaves the semantic pecularity of nouns like *passenger* and *batter* to be explained. Let us call them **phase nouns** (another possibility would be 'stage nouns'; however, Carlson's notion of a stage serves basically to reconstruct events, and it is difficult to see, for example, a passenger as an event). I will come back to phase nouns in Section (4.5).

1.3. *A New Solution*

I will present a different solution to the event-related readings of (1). It is couched in a more general framework for the semantics of mass nouns, count nouns, measure constructions, and temporal constitution (i.e., aspectual classes), which was developed in Krifka (1986, to appear). This framework takes on the one hand the treatment of mass nouns and plural nouns in an algebraic (1attice-theoretic) semantics, as developed by Link (1983), and the event semantics developed by Davidson (1967) and Parsons (1980) on the other (cf. Hinrichs, 1985; Bach, 1986; Link, 1987; and Lasersohn, 1988 for related approaches). Furthermore, it combines them with notions developed in the theory of measurement to handle cases like *four thousand ships*, *sixty tons of radioactive waste*, or *snore for two hours*.

In Section (2), I will outline this framework as far as it is necessary to understand my analysis of event-related readings. In Section (3), I will present two versions of this analysis, the second of which is semantically somewhat more complicated, but more in agreement with the syntactic structure. In Section (4), I will go into some cases which seem to pose special problems for at least one of the two analyses – namely, coordi-

nation, quantifiers, comparison, anaphora, and phase nouns. Finally, I will argue that the event-related readings of our examples are a special case of a more common phenomenon, which in general can be described as the extension of measure functions from one domain to another.

2. Lattice sorts and measurement

2.1. *Lattice Sorts*

In order to treat phenomena like the semantics of mass terms and plural terms, we have to assume that the universe of entities of a sort has a certain structure, which we will call **lattice sort**. Most important, we have to guarantee that if we have two entities x, y of a given sort Σ (which is assumed to be non-empty), there is a sum object or **join** $x \cup_\Sigma y$, the entity which consists of x and y. It is natural to claim that $\cup_\Sigma$ is **commutative, idempotent** and **associative**. Furthermore, it is natural to call x (and y) a **part** of the object $x \cup_\Sigma y$; if an entity x is part of an entity y, we write $x \subseteq_\Sigma y$. According to this definition, every entity is a part of itself, as $\subseteq_\Sigma$ is reflexive; but we can define the relation of a **proper part** as the irreflexive relation $\subset_\Sigma$ corresponding to $\subseteq_\Sigma$. We can say what it means that two entities x, y **overlap**, which we render as $x \circ_\Sigma y$: This is the case if x and y have a common part z. It is reasonable to claim that there is no element in Σ which is part of every element, that is, Σ should have **no bottom element**. To be sure that the join operation is **complete**, that is, that we can join any number of elements (even an infinite number), we claim that for any non-empty subset of Σ there exists an upper bound in Σ. We can then introduce the notion of a **supremum**, called $\sup_\Sigma$, of a non-empty subset of Σ as its least upper bound, as it can be shown that the least upper bound is unique. This guarantees, of course, that for every x, y in Σ, there is an element $x \cup_\Sigma y$ in Σ, as $x \cup_\Sigma y$ is the least upper bound of $\{x, y\}$. Thus, we arrive at the structure of a **(complete) join semi-lattice** (cf. Grätzer, 1971, p. 8), which was used in Link (1983, 1987). We furthermore require that the semi-lattice is **distributive**. This can be enforced by two additional claims: First, we claim that whenever x is a proper part of y, there is another part of y which does not overlap x (**witness element**). Second, we claim that whenever x is a part of the join of y and z, then x is a part of y, or of z, or partly of y and partly of z (**partition**).

To sum up, we have the following postulates for lattice sorts. I distinguish 'axioms' which restrict the class of admissible structures from 'definitions' which introduce new symbols as a shorthand.

(3) Σ is a **lattice sort** with join $\cup_\Sigma$, part $\subseteq_\Sigma$, proper part $\subset_\Sigma$, overlap

$\circ_\Sigma$ and supremum $\sup_\Sigma$ if and only if the following conditions hold. We assume that x, y, z, x', x'' are variables ranging over Σ:

a. (Ax.) $x \cup_\Sigma y = y \cup_\Sigma x$ (commutativity)
b. (Ax.) $x \cup_\Sigma x = x$ (idempotency)
c. (Ax.) $x \cup_\Sigma [y \cup_\Sigma z] = [x \cup_\Sigma y] \cup_\Sigma z$ (associativity)
d. (Def.) $x \subseteq_\Sigma y \leftrightarrow x \cup_\Sigma y = y$ (part)
e. (Def.) $x \subset_\Sigma y \leftrightarrow x \subseteq_\Sigma y \wedge \neg x = y$ (proper part)
f. (Def.) $x \circ_\Sigma y \leftrightarrow \exists z[z \subseteq_\Sigma x \wedge z \subseteq_\Sigma y]$ (overlap)
g. (Ax.) $\neg\exists x\forall y[x \subseteq_\Sigma y]$ (no bottom element)
h. (Ax.) $\forall X[X \subseteq \Sigma \wedge X \neq \emptyset \rightarrow \exists x\forall y[y \in X \rightarrow y \subseteq_\Sigma x]]$ (completeness)
i. (Def.) $\forall X[X \subseteq \Sigma \wedge X \neq \emptyset \rightarrow \sup_\Sigma(X) = \iota x[\forall y[y \in X \rightarrow y \subseteq_\Sigma x] \wedge \forall x'[\forall y[y \in X \rightarrow y \subseteq_\Sigma x'] \rightarrow x \subseteq_\Sigma x']]]$ (supremum)
j. (Ax.) $x \cup_\Sigma y \rightarrow \exists z[\neg z \circ_\Sigma x \wedge z \subseteq_\Sigma y]$ (witness element)
k. (Ax.) $x \subseteq_\Sigma [y \cup_\Sigma z] \rightarrow x \subseteq_\Sigma y \vee x \subseteq_\Sigma z \vee \exists x', x''[x' \subseteq_\Sigma y \wedge x'' \subseteq_\Sigma z \wedge x = x' \cup_\Sigma x'']$ (partition)

It can be shown that the structure described by (3) is a **Boolean algebra wth the bottom element removed** (and thus can be characterized by different sets of axioms). To see this, note that we can construct from a lattice sort Σ a set Σ_0 with two elements $\mathbf{0}$ and $\mathbf{1}$, two binary operations $\cup$, $\cap$ and a unary operation $-$ on Σ_0 as follows:

(4)a. $\mathbf{0}$ is an object not occuring in Σ, $\neg\mathbf{0} \in \Sigma$;
b. $\Sigma_0 = \Sigma \cup \{\mathbf{0}\}$;
c. $\mathbf{1} = \sup_\Sigma(\Sigma)$;
d. for every $x \in \Sigma_0$, $x \cup \mathbf{0} = \mathbf{0} \cup x = x$;
e. for every $x, y \in \Sigma$, $x \cup y = x \cup_\Sigma y$;
f. for every $x \in \Sigma_0$, $x \cap \mathbf{0} = \mathbf{0} \cap x = \mathbf{0}$;
g. for every $x, y \in \Sigma$, if $x \circ y$ then $x \cap y = \sup_\Sigma(\{z: z \subseteq_\Sigma x \wedge z \subseteq_\Sigma y\})$, else $x \cap y = y \cap x = \mathbf{0}$;
h. for every $x \in \Sigma$ with $x \neq \mathbf{1}$, $-x = \sup_\Sigma(\{z: \neg z \subseteq_\Sigma x\})$;
i. $-\mathbf{0} = \mathbf{1}$; $-\mathbf{1} = \mathbf{0}$.

To prove that $\langle\Sigma_0, \cup, \cap, -, \mathbf{0}, \mathbf{1}\rangle$ is a Boolean algebra, we have to show that $\langle\Sigma_0, \cup, \cap\rangle$ is a **complemented distributive lattice** (in its algebraic definition) with $-$ as complement operation and $\mathbf{0}$, $\mathbf{1}$ as greatest lower bound (bottom) and least upper bound (top), respectively (see e.g. Grätzer, 1971, p. 58).

First, we have to show that $\langle\Sigma_0, \cup, \cap\rangle$ is a **lattice**. It is clear from

the definition of $\cup$ that this operation is commutative, associative and idempotent. – The operation $\cap$ is commutative: If $\neg x \circ y$, we have $x \cap y = y \cap x$ $(=\mathbf{0})$ by definition; else we have $x \cap y = \sup_\Sigma(\{u: u \subseteq_\Sigma x \wedge u \subseteq_\Sigma y\}) = \sup_\Sigma(\{u: u \subseteq_\Sigma y \wedge u \subseteq_\Sigma x\}) = y \cap x$. – The operation $\cap$ is idempotent: If $x = \mathbf{0}$, we have $x \cap x = x$ $(=\mathbf{0})$ by definition; else we have $x \cap x = \sup_\Sigma(\{u: u \subseteq_\Sigma x \wedge u \subseteq_\Sigma x\}) = \sup_\Sigma(\{u: u \subseteq_\Sigma x\}) = x$ (to see the last step, note that x is an upper bound of $\{u: u \subseteq_\Sigma x\}$, and if there were an x' with $x' \subset_\Sigma x$ which is also an upper bound of $\{u: u \subseteq_\Sigma x\}$, we would have to require $x \subseteq_\Sigma x'$, which is a contradiction). – The operation $\cap$ is associative: If one of x, y, z is $\mathbf{0}$, then we have $x \cap [y \cap z] = [x \cap y] \cap z$ $(=\mathbf{0})$ by definition. If one of the three pairs out of x, y, z does not overlap, it can be shown that $x \cap [y \cap z] = [x \cap y] \cap z$ $(=\mathbf{0})$. (For example, if $\neg y \circ_\Sigma z$, then the left side is $\mathbf{0}$ by definition and the right side is $\mathbf{0}$, as we can show that even if $x \circ_\Sigma y$, we have $\neg[x \cap y] \circ_\Sigma z$). If all of the three pairs out of x, y, z overlap, we have $x \cap [y \cap z] = \sup_\Sigma(\{u: u \subseteq_\Sigma x \wedge u \subseteq_\Sigma \sup_\Sigma(\{u: u \subseteq_\Sigma y \wedge u \subseteq_\Sigma z\})\}) = \sup_\Sigma(\{u: u \subseteq_\Sigma x \wedge u \subseteq_\Sigma y \wedge u \subseteq_\Sigma z\}) = \sup_\Sigma(\{u: u \subseteq_\Sigma \sup_\Sigma(\{u: u \subseteq_\Sigma x \wedge u \subseteq_\Sigma y\}) \wedge u \subseteq_\Sigma z\}) = [x \cap y] \cap z$. – Furthermore, we can prove absorption, that is $x \cap [x \cup y] = x$ and $x \cup [x \cap y] = x$. For the first absorptive law, we have to distinguish two cases: If $x = \mathbf{0}$, we have $\mathbf{0} \cap (\mathbf{0} \cup y) = \mathbf{0} \cap y = \mathbf{0}$ by definition; if $x \neq \mathbf{0}$, we have $x \cap [x \cup y] = \sup_\Sigma(\{u: u \subseteq_\Sigma x \wedge u \subseteq_\Sigma [x \cup y]\}) = \sup_\Sigma(\{u: u \subseteq_\Sigma x\}) = x$. For the second absorptive law, we also have to distinguish two cases: If $\neg x \circ_\Sigma y$, we have $x \cup [x \cap y] = x \cup \mathbf{0} = x$ by definition; if $x \circ_\Sigma y$, we have $x \cup [x \cap y] = x \cup \sup_\Sigma(\{z: z \subseteq_\Sigma x \wedge z \subseteq_\Sigma y\}) = \sup_\Sigma(\{z: z \subseteq_\Sigma x \vee [z \subseteq_\Sigma x \wedge z \subseteq_\Sigma y]\}) = \sup_\Sigma(\{z: z \subseteq_\Sigma x\}) = x$. Note that this proof uses axioms (3a–c, h).

Second, we have to show that $\langle \Sigma_0, \cup, \cap \rangle$ is a **complemented** lattice, that is, a bounded lattice where every element has a complement. First take boundedness. By definition, we have $\mathbf{0}$ as the bottom element, with $x \cup \mathbf{0} = x$ and $x \cap \mathbf{0} = \mathbf{0}$ for every $x \in \Sigma_0$. We can prove that $\mathbf{1}$ is the top element, as it holds for every $x \in \Sigma_0$ that $x \subseteq_\Sigma \mathbf{1}$, and hence $x \cup \mathbf{1} = \mathbf{1}$, and that $x \cap \mathbf{1} = \sup_\Sigma(\{z: z \subseteq_\Sigma x \wedge z \subseteq_\Sigma \mathbf{1}\}) = \sup_\Sigma(\{z: z \subseteq_\Sigma x\}) = x$. Now take complementation. By definition, the complement of $\mathbf{1}$ is $\mathbf{0}$ and the complement of $\mathbf{0}$ is $\mathbf{1}$. For every $x \in \Sigma_0$ with $x \neq \mathbf{0}$, $\mathbf{1}$ we have as a complement $\sup_\Sigma(\{z: \neg z \subseteq_\Sigma x\})$. Note that the set $\{z: \neg z \subseteq_\Sigma x\}$ is non-empty for $x \neq \mathbf{1}$ because the existence of a witness element (3j). Its supremum exists because of completeness (3h), and is provable unique. By (3j), we get a **modular** lattice (cf. Grätzer, p. 70), as we exclude so-called pentagon sublattices (see Figure 1; here, x is a proper part of y, but the lattice does not contain a contrary element of x with respect to y).

Third, we have to show that $\langle \Sigma_0, \cup, \cap \rangle$ is a **distributive** lattice. Distributive lattices (lattices in which the distributive laws hold, e.g. $x \cup [y \cap z] =$

$[x \cup y] \cap [x \cap z]$) can be characterized as modular lattices which do not have the diamond (Figure 2) as a sublattice (cf. Grätzer, 1971, p. 70). The diamond is excluded by (3k), as x is a part of w, which is $y \cup z$, and x is neither a part of y, nor of z, nor partly of y and partly of z. Note that we could have excluded the pentagon and the diamond at once by claiming that complements are unique (in both figures, z has two complements, x and y).

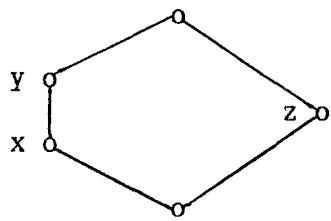

Fig. 1.

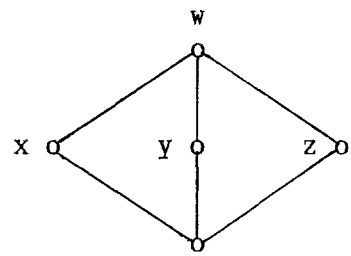

Fig. 2.

As examples of lattice sorts, we consider objects (which subsume quantities of matter) and events, which we call O and E, respectively. We assume that they are disjoint from each other.

(5) Lattice Sorts:
  a. Objects: O, with $\cup_O$, $\subseteq_O$, $\subset_O$, $\circ_O$, variables u, u' . . .
  b. Events: E with $\cup_E$, $\subseteq_E$, $\subset_E$, $\circ_E$, variables e, e' . . .
  O and E are disjoint: $\neg\exists x[O(x) \wedge E(x)]$

In lattice sorts, we can specify the **cumulative reference property** (cf. Quine, 1960) of bare mass nouns like *waste*, bare plurals like *ships*, and expressions like *John snores* if they are taken as pure event predicates. This property says that if we have, say, two entities which are ships, then their join is again an entity which is ships. In the general case, we claim that for every subset of the extension of a cumulative predicate, its supremum is in the extension of that predicate as well. On the other hand, we can specify what I have called the **quantized reference property** of nominal predicates like *sixty tons of waste*, *four thousand ships*, or *snore for two hours*. This property says that if we have, say, an entity which is four thousand ships, then it does not have a proper subpart which is again four thousand ships.

We can define predicates which are cumulative or quantized with respect to Σ as follows:

(6) If Σ is a lattice sort, then
  (i) Cumulative Predicates:
  $\mathbf{CUM}_\Sigma(P) \leftrightarrow P \subseteq \Sigma \wedge \forall X[X \subseteq P \wedge X \neq \emptyset \rightarrow P(\sup_\Sigma(X))]$
  Examples: *waste*, *ships*, *snore*.

(ii) Quantized Predicates:
$\mathbf{QUA}_\Sigma(\mathrm{P}) \leftrightarrow \mathrm{P} \subseteq \Sigma \wedge \forall x \forall x'[\mathrm{P}(x) \wedge \mathrm{P}(x') \rightarrow \neg x' \subset_\Sigma x]$
Examples: *sixty tons of radioactive waste*, *four thousand ships*, *snore for three hours*.

In the next section, we will see how constructions like *sixty tons of radioactive waste* or *four thousand ships* can be analyzed.

2.2. *Measure Functions on Lattices*

Obviously, we will need some sort of measure functions. For example, entities which are sixty tons of radioactive waste are radioactive waste which weighs 60 tons. We will develop the notions of measurement theory only as far as we need them; see, e.g., Suppes and Zinnes (1963), Krantz e.a. (1971) for a more thorough treatment.

A **measure function** is a function from concrete entities to abstract entities such that certain structures of the concrete entities, the **empirical relations**, are preserved in certain structures of the abstract entities, normally **arithmetical relations**. That is, measure functions are **homomorphisms** which preserve an empirical relation in an arithmetical relation. For example, a measure function like °C 'degree Celsius' is such that the empirical relation 'x is cooler than y' is reflected in the linear order of numbers, as it holds that $°\mathrm{C}(x) < °\mathrm{C}(y)$.

We are interested in a special class of measure functions, namely **extensive measure functions**. For them, we have in addition an empirical operation, called **concatenation**, which is reflected in the arithmetical addition. For example, a measure function like **m** 'meter' is such that for any x, y, $\mathbf{m}(x$ concatenated with $y)$ equals $\mathbf{m}(x) + \mathbf{m}(y)$.

We can apply the notion of extensive measure functions to lattice sorts and define the notion of measure functions compatible with a lattice sort as measure functions whose domain is a subset of the lattice sort, which are positive, which can be extended to parts, and which are additive with respect to the join (for this property cf. also Cartwright, 1975; ter Meulen, 1980):

(7) μ is a measure function **compatible with** a lattice sort Σ iff
a. $\mu(x) = n \rightarrow \Sigma(x) \wedge n \in \mathbb{R}$
(μ's domain is a subset of Σ, μ's range is a subset of the reals)
b. $\mu(x) = n \rightarrow \mu(x) > 0$ (positivity)
c. $\mu(x) = n \wedge y \subseteq_\Sigma x \rightarrow \exists n'[\mu(y) = n']$ (extendability to parts)
d. $\neg x \circ_\Sigma y \wedge \mu(x) = n \wedge \mu(y) = n' \rightarrow \mu(x \cup_\Sigma y) = n + n'$ (additivity)

Note that the last claim requires that the lattice sort excludes the diamond

(without bottom element) as a sublattice, that is, satisfies partition (3k). Otherwise (as one referee pointed out) we could have three non-overlapping elements x, y, z with $x \cup_\Sigma y = x \cup_\Sigma z$ and hence $\mu(x \cup_\Sigma y) = \mu(x \cup_\Sigma y)$, but there is no guarantee that $\mu(y) = \mu(z)$.

We can show that we can build quantized predicates of a lattice sort out of measure functions which are compatible with that lattice sort:

(8) If μ is a measure function compatible with a lattice sort Σ and n is a number, then $\mathbf{QUA}_\Sigma(\lambda x[\mu(x) = n])$.

Proof. Assume to the contrary that $\lambda x[\mu(x) = n]$ is not quantized, that is, that there are two individuals x_1, x_2 with $x_2 \subset_\Sigma x_1$, $\mu(x_1) = n$, $\mu(x_2) = n$. Because of the distributivity of the lattice sort, there is a unique complement x_3 of x_2 such that $\neg x_2 \circ_\Sigma x_3$ and $x_2 \cup_\Sigma x_3 = x_1$. Because of extendability to parts, x_3 is in the domain of μ as well, and because of positivity, $\mu(x_3) = n' > 0$. Now, we have $\mu(x_1) = \mu(x_2 \cup_\Sigma x_3)$ (as x_1 is $x_2 \cup_\Sigma x_3$) $= \mu(x_2) + \mu(_3)$ (because of additivity, as x_2 and x_3 do not overlap) $= n + n' > n$ (as n' is greater than 0). We arrive thus at the contradiction $\mu(x_1) = n$ and $\mu(x_1) > n$. – Note that we made essential use of distributivity to derive this, that is, the axioms of witness element and partition (3j, k) are essential.

Let us look at an example. If we interpret *ton* as a measure function compatible with the object lattice, we can give *sixty tons of radioactive waste* the following interpretation. The tree (9) simultaneously shows the syntactic and semantic composition. Syntactic composition is specified by categorial grammar rules, where N is the category of nouns and Nu the category of number words. Semantic composition is by type-driven lambda application. That is, if SEM represents the two-place operation of semantic composition and α, β are two semantic representations, then SEM(α, β) equals $\alpha(\beta)$ or $\beta(\alpha)$, depending which is well-formed; if none is well-formed, SEM(α, β) is undefined. I assume that *of* is inserted at the surface (cf. Akmajian and Lehrer 1977).

(9) *tons* [(N/N)/Nu]
$\lambda n \lambda \mathrm{P} \lambda u[\mathrm{P}(u) \wedge \mathbf{ton}'(u) = n]$

sixty [Nu]
60

sixty tons [N/N]
$\lambda \mathrm{P} \lambda u[\mathrm{P}(u) \wedge \mathbf{ton}'(u) = \mathbf{60}]$

radioactive waste [N]
$\lambda u[\mathbf{radioactive\_waste}'(u)]$
/
sixty tons of radioactive waste [N]
$\lambda u[\mathbf{radioactive\_waste}'(u) \wedge \mathbf{ton}'(u) = \mathbf{60}]$

We can show with (8) that this is a quantized predicate for objects, provided that **ton**′ is a measure function which is compatible with the object lattice.

To handle count noun constructions in the same way, we have to assume that they have a measure function built into their semantic representation. To keep things simple (see Krifka, 1986, to appear for a more thorough treatment in which count noun meanings are split up into a qualitative and a quantitative component), we assume that a count noun like *ship* is represented by a relation $\lambda n \lambda u[\mathbf{ship}'(u) = n]$, where **ship**′ is a measure function which is compatible with the object lattice. We call such a relation **measure relation**. A count noun construction like *four thousand ships* can be represented as follows:

(10) *ships* [N/Nu]
$\lambda n \lambda u[\mathbf{ship}'(u) = n]$

four thousand [Nu]
4000
/
four thousand ships [N]
$\lambda n[\mathbf{ship}'(u) = \mathbf{4000}]$

We can again prove that this is a quantized predicate. Here, I assume that the singular/plural distinction is a pure syntactic agreement phenomenon. This is justified, as there are cases in which the number word denotes the number 1 and nevertheless the noun must be plural, as in *1.0 ships* (vs. **1.0 ship*).

3. A TREATMENT OF OBJECT-RELATED AND EVENT-RELATED READINGS

Now we are ready to tackle the explanation of the readings of our examples in (1). We will concentrate here on our basic Example (1a). For reason of simplicity, we will not represent the whole sentence, but only the part *four thousand ships pass through the lock*, omitting tense and the temporal adverbial.

3.1. *The Object-Related Reading*

I will start by modelling the object-related reading, to give some impression of the general outlook of the semantic framework which is de-

veloped in more detail in Krifka (to appear). To keep things simple, we will treat only one-place verbal predicates and represent *pass through the lock* as a relation between objects and events, similar to Davidson (1967). Call this an **event relation**. We then can have derivations of complex event predicates like the following one:

(11) *pass through the lock* [V/NP]
$\lambda u \lambda e[\mathbf{pass\_through\_the\_lock}'(e,u)]$

ships [N/Nu]
$\lambda n \lambda u[\mathbf{ship}'(u) = n]$

four thousand [Nu]
4000

four thousand ships [N]
$\lambda u[\mathbf{ship}'(u) = \mathbf{4000}]$

$\emptyset$[NP/N]
$\lambda Q \lambda R \lambda e \exists u[R(e,u) \wedge Q(u)]$

four thousand ships [NP]
$\lambda R \lambda e \exists u[R(e,u) \wedge \mathbf{ship}'(u) = \mathbf{4000}]$

four thousand ships pass through the lock [V]
$\lambda e \exists u[\mathbf{pass\_through\_the\_lock}'(e,u) \wedge \mathbf{ship}'(u) = \mathbf{4000}]$

We end up with a predicate that applies to events of lock traversals by four thousand ships.

Of course, we should have rules which tell us under which condition this predicate applies to an event. One sufficient condition is that there are 4000 ships, each of which passed through the lock. This can be captured if we assume summativity for the relation **pass_through_the_lock**′ (cf. Krifka, to appear):

(12) A relation R is **summative** iff $R(x, y) \wedge R(x', y') \rightarrow R(x \cup_\Sigma x', y \cup_\Sigma y')$, for appropriate $\Sigma = E, O$

Example. A simple example may be handy to see how the treatment of the object-related reading works. Consider the two ships Candida and Eleonore, which are represented by the objects **Candida**′ and **Eleonore**′, respectively. Assume that Candida passes through the lock once (call this event e_1), and Eleonore passes through the lock twice (call these events e_2 and e_3). The sum of these events can be represented as $e_1 \cup_E e_2 \cup_E e_3$

(because of associativity, we don't need brackets). Furthermore, we assume that the event relation **pass_through_the_lock**′ is summative and that **ship**′ is an extensive measure function compatible with the object lattice, from which it follows that **Candida**′ $\cup_O$ **Eleonore**′ has the value 2 on this measure function. All this can be represented by the following formulae:

(13)a. **ship**′(**Candida**′) = **1**
b. **ship**′(**Eleonore**′) = **1**
c. **pass_through_the_lock**′(e_1, **Candida**′)
d. **pass_through_the_lock**′(e_2, **Eleonore**′)
e. **pass_through_the_lock**′(e_3, **Eleonore**′)
f. **pass_through_the_lock**′ is summative
g. **ship**′(**Candida**′ $\cup_O$ **Eleonore**′) = **2**

From (c–f) it follows that

(13)h. **pass_through_the_lock**′($e_1 \cup_E e_2 \cup_E e_3$, **Candida**′ $\cup_O$ **Eleonore**′ $\cup_O$ **Eleonore**′)

and, because of idempotency of the $\cup_O$-relation, this equals

(13)i. **pass_through_the_lock**′($e_1 \cup_E e_2 \cup_E e_3$, **Candida**′ $\cup_O$ **Eleonore**′)

from which it follows by (g) that

(13)j. $\exists u$[**pass_through_the_lock**′($e_1 \cup_E e_2 \cup_E e_3, u$) $\wedge$ **ship**′(u) = **2**]

So we can prove that $e_1 \cup_E e_2 \cup_E e_3$ falls under the object-related reading of *two ships pass through the lock.*

In (11), we only have derived an **event predicate** as a semantic representation of our example sentence. Let us call the syntactic category which represents that stage of the derivation the **sentence radical**. Sentence radicals can be transformed into sentences by **sentence mood operators**. For example, the **declarative operator** takes an event predicate and yields a formula. Here, I simply assume that the declarative operator existentially binds the event variable of the meaning of the sentence radical. Look at the following example:

(14) *four thousand ships pass through the lock* [V]
$\lambda e \exists u$[**pass_through_the_lock**′(e) $\wedge$ **ship**′(u) = **4000**]

DECL[S/V]
λP$\exists e$[P(e)]
/

four thousand ships pass through the lock [S]
$\exists e \exists u$[**pass_through_the_lock**′(e, u) $\wedge$ **ship**′(u) = **4000**]

In the following, we will develop our derivations only up to the level of the sentence radical.

3.2. *The Event-Related Reading, First Approach*

The first approach to the event-related reading of *four thousand ships pass through the lock* consists in the derivation of a new measure function, call it μ, by the predicate *pass through the lock*, which is a predicate on events, and the measure function inherent in the meaning of *ship*, which is a measure function on objects. This new measure function maps events to a number – the number of lock traversals by a single ship. The whole expression *four thousand ships pass through the lock* then applies to events which have the value 4000 on this measure function.

How can we construct the new measure function μ from the meaning of *pass through the lock* and the meaning of *ship*? We have to proceed in two steps, which I call standardization and generalization.

First, μ can be **standardized** with the object-related interpretation of *n ships pass through the lock*. This is because under certain circumstances, the object-related reading and the event-related reading of *n ships pass through the lock* coincide, namely in cases where every ship passes through the lock at most once. We will call these circumstances **non-iterative** models of *n ships pass through the lock*.

Secondly, μ can be **generalized** by claiming additivity. That is, we claim that for any two nonoverlapping events e, e': If e is a passing through the lock of n ships, and e' is a passing through the lock of n' ships, then $e \cup_E e'$, the join of e and e', should be a passing through the lock of $n + n'$ ships.

In order to work out this analysis, we have to define the notion of an **iterative event**. An event e is called iterative with respect to some event relation R if there is an object u which stands in R-relation to at least two different parts of e:

(15) $\mathbf{ITER}(e, \mathrm{R}) \leftrightarrow \exists u, e', e''[e' \subseteq_E e \wedge e'' \subseteq_E e \wedge e' \neq e'' \wedge \mathrm{R}(e', u) \wedge \mathrm{R}(e'', u)]$

Example. The event $e_1 \cup_E e_2 \cup_E e_3$, as introduced in (13), is an iterative event with respect to the event relation **pass_through_the_lock**′, as one object (the ship **Eleonore**′) stands in that relation to two different parts of $e_1 \cup_E e_2 \cup_E e_3$ (namely to e_2 and to e_3).

Now we can define an operator **OEM** which takes a measure relation and an event relation and yields the measure function for events that we need.

(16) Let δ be a measure relation and α an event relation. Then the operator **OEM** (for *O*bject-induced *E*vent *M*easure Functions) can be defined as follows:
OEM(δ, α) = the measure function μ with the smallest domain such that
(i) Standardization: $\neg$**ITER**$(e, \alpha) \rightarrow [\mu(e) = n \leftrightarrow \exists u[\delta(n, u) \wedge \alpha(e, u)]]$
(ii) (Generalization): $\neg e \circ_{\mathrm{E}} e' \wedge \mu(e) = n \wedge \mu(e') = n' \rightarrow \mu(e \cup_{\mathrm{E}} e') = n + n'$

As an example, look at the treatment of the event-related reading of *four thousand ships pass through the lock*:

(17) *pass through the lock* [V/NP]
pass_through_the_lock$'$

ships [N/Nu]
$\lambda n \lambda u[\mathbf{ship}'(u) = n]$

$\emptyset$[(NP/Nu)/(N/Nu)]
$\lambda \mathrm{R}' \lambda \mathrm{R} \lambda n \lambda e[\mathbf{OEM}(\mathrm{R}', \mathrm{R})(e) = n]$
/

ships [NP/Nu]
$\lambda \mathrm{R} \lambda n \lambda e[\mathbf{OEM}(\lambda n \lambda u[\mathbf{ship}'(u) = n], \mathrm{R})(e) = n]$
/

ships pass through the lock [V/Nu]
$\lambda n \lambda e[\mathbf{OEM}(\lambda n \lambda u[\mathbf{ship}'(u) = n], \mathbf{pass\_through\_the\_lock}')(e) = n]$

four thousand [Nu]
4000
/

four thousand ships pass through the lock [V]
$\lambda e[\mathbf{OEm}(\lambda n \lambda u[\mathbf{ship}'(u) = n], \mathbf{pass\_through\_the\_lock}')(e) = \mathbf{4000}]$

We assume functional composition as a syntactic rule, so we can combine *pass through the lock* [V/NP] with *ships* [NP/Nu] to an expression of the category [V/Nu]. – According to (16), the object-induced measure function for events in this example is the following one:

(18) **OEM**($\lambda n \lambda u[\mathbf{ship}'(u) = n]$, **pass_through_the_lock**$'$) is the smallest measure function μ such that:

(i) (Standardization): $\neg$**ITER**(e, **pass_through_the_lock**$') \rightarrow$ $[\mu(e) = n \leftrightarrow \exists u[\mathbf{ship}'(u) = n \wedge \mathbf{pass\_through\_the\_lock}'(e, u)]$

(ii) (Generalization): $\neg e \circ_{\mathrm{E}} e' \wedge \mu(e) = n \wedge \mu(e') = n' \rightarrow \mu(e \cup_{\mathrm{E}} e') = n + n'$

This measure function μ is the one we are looking for: If μ is applied to an event e which is non-iterative with respect to the event relation, it gives us the number of ships which passed through the lock in e (if e is an event of ships passing through the lock at all). This can be derived via rule (i), standardization. If μ is applied to other events, it is defined only if there is a partition of e into non-overlapping events $e_1, e_2, \ldots, e_m$ such that for any of these events, μ yields a value according to rule (i). By additivity (ii), then, μ yields a value for the join of the events $e_1, e_2, \ldots, e_m$ as well.

Example. We are looking for the value of the measure function as defined in (18) for the event $e_1 \cup_{\mathrm{E}} e_2 \cup_{\mathrm{E}} e_3$, the lock traversals by the ships Candida and Eleonore:

(19) $\mathbf{OEM}(\lambda n \lambda u[\mathbf{ship}'(u) = n],$ $\mathbf{pass\_through\_the\_lock}')(e_1 \cup_{\mathrm{E}} e_2 \cup_{\mathrm{E}} e_3)$

To determine the value of this function, we cannot employ directly the standardization clause, as $e_1 \cup_{\mathrm{E}} e_2 \cup_{\mathrm{E}} e_3$ is an iterative event with respect to the event relation. But there is a partition of $e_1 \cup_{\mathrm{E}} e_2 \cup_{\mathrm{E}} e_3$ into two non-overlapping events, for example $e_1 \cup_{\mathrm{E}} e_2$ and e_3, which are not iterative. For them the following holds by standardization:

(20)a. $\mathbf{OEM}(\lambda n \lambda u[\mathbf{ship}'(u) = n], \mathbf{pass\_through\_the\_lock}')(e_1 \cup_{\mathrm{E}} e_2) = 2$

b. $\mathbf{OEM}(\lambda n \lambda u[\mathbf{ship}'(u) = n], \mathbf{pass\_through\_the\_lock}')(e_3) = 1$

And by generalization, we have

(20)c. $\mathbf{OEM}(\lambda n \lambda u[\mathbf{ship}'(u) = n],$ $\mathbf{pass\_through\_the\_lock}')(e_1 \cup_{\mathrm{E}} e_2 \cup_{\mathrm{E}} e_3) = 3$

Therefore we can conclude that $e_1 \cup_E e_2 \cup_E e_3$ falls under the event-related reading of *three ships passed through the lock*.

If we define a new measure function as we did right now, we have to check at least two things. The first is whether the standardization rule and the generalization rule are in conflict with each other. Obviously, this is not the case according to our definition. For example, if we have an event e which consists of the non-iterative passing through the lock by five ships, then the standardization clause gives us the value 5 if we apply μ to e.

Furthermore, we can find a partition of e into e' and e'' such that e' is the passing of two ships and e'' is the passing of three ships (according to standardization), and the generalization clause (ii) tells us again that the join $e' \cup_E e'' = e$ has the value 5. – Second, we have to check whether the induced measure function is as general as it should be. It is evident that any event for which the event-related reading of *four thousand ships passed through the lock* holds can be broken down into non-iterative lock traversals of the ships involved. So, our reconstruction should be indeed general enough.

Our analysis of event-related readings yields the right result even for the mass noun case, for example in *sixty tons of radioactive waste passed through the lock*. The definition of the object-induced event measure function covers measures on matter as well, as the notion of iterativity applies to matter in the same way as it applies to objects. So, we derive an analysis of the event-related reading even in this case. It is essential to the syntactic analysis that, contrary to the measure construction we had in (9), *tons* is first applied to *radioactive waste*, so that the number argument remains unbound. This can be done by some liberal rules of category combination.

An argument against the treatment of event-related readings as developed here is that the syntactic structures we had to assume seem to be motivated only by the semantic analysis. With our example *four thousand ships pass through the lock*, we first had to combine the count noun *ships* with the verbal predicate *pass through the lock*, and only then were we able to add the number word *four thousand*. From a purely syntactic standpoint, however, *four thousand* clearly forms a constituent with *ships*. The problem is even worse with examples like *sixty tons of radioactive waste pass through the lock*. Here, the number word must be combined with *tons of radioactive waste pass through the lock*, although syntactically it combines to a constituent not only with *tons of radioactive waste*, but even with the measure noun *tons*.

There are different ways to get a semantic representation which is more in tune with the ordinary syntactic structure. One is to raise the type of the number word so that it takes a count noun relation and an event relation. For example, we would have to analyze *four thousand* as follows to get the event-related reading:

(21) *pass through the lock* [V/NP]
pass_through_the_lock'

four thousand [(V/(V/NP))/(N/Nu)]
$\lambda R \lambda R' \lambda e[\mathbf{OEM}(R, R')(e) = \mathbf{4000}]$

ships [N/Nu]
$\lambda n \lambda u[\mathbf{ship}'(u) = n]$
/
four thousand ships [V/(V/NP)]
$\lambda R' \lambda e[\mathbf{OEM}(\lambda n \lambda u[\mathbf{ship}'(u) = n], R')(e) = \mathbf{4000}]$
/
four thousand ships pass through the lock
$\lambda e[\mathbf{OEM}(\lambda n \lambda u[\mathbf{ship}'(u) = n], \mathbf{pass\_through\_the\_lock}')(e) = \mathbf{4000}]$

I will not try to generalize this approach, but develop another one which may seem more natural.

3.3. *The Event-Related Reading, Second Approach*

The general idea of the second approach is this: We construct from the meaning of the verbal predicate alone, in the case at hand *pass through the lock*, a measure function on events. The nominal predicate, e.g., *four thousand ships*, then specifies a value of this measure function. Both the construction of the measure function and the specification of the value is built into the meaning of a special determiner, which is responsible for this reading.

In this approach, the values of the measure function cannot be ordinary numbers; they are predicate extensions instead. Do they have the right arithmetical properties? The set of values of extensive measure functions must have at least an addition operation. Now, it is possible to define a suitable addition operation in a lattice sort, namely, an operation on the quantized subsets of this lattice sort. The definition runs as follows:

(22) If Σ is a lattice sort, then we can define an addition $+_\Sigma$ for subsets P, P′ of Σ:
$P +_\Sigma P' = \lambda x'' \exists x \exists x'[P(x) \wedge P'(x') \wedge \neg x \circ_\Sigma x' \wedge x'' = x \cup_\Sigma x']$

In prose: The 'sum' of the sets P and P′ is the set of all elements which consist of two nonoverlapping parts which are elements of P and P′, respectively. If we take only those subsets which are quantized with respect to the lattice sort, $+_\Sigma$ mirrors the essential properties of the addition operation of numbers. Thus, we can use quantized predicates, instead of numbers, as the range of measure functions. Let us call quantized predicates **degrees**, and $+_\Sigma$ **degree addition**

As an example, consider the measure function **ship**′. This is an extensive measure function compatible with the object lattice, so the addition oper-

ation for 'ship degrees' is $+_O$. We can check that the $+_O$-addition of the degree represented by *four thousand ships* and the degree represented by *five thousand ships* yields the degree *nine thousand ships*, as any two non-overlapping objects which consist of four thousand ships and five thousand ships, respectively, have an object which consists of nine thousand ships as their $\cup_O$-join.

(23) **ship**′ is an extensive measure function compatible with the object lattice. We have:
$\lambda u[\mathbf{ship}'(u) = \mathbf{4000}] +_O \lambda u[\mathbf{ship}'(u) = \mathbf{5000}] = \lambda u[\mathbf{ship}'(u) = \mathbf{9000}]$

In order that these definitions work as they are intended to, we obviously have to guarantee that there are enough entities of the right sort in the universe – in our example, that there are enough ships. This can be accomplished if we reconstruct degrees in an intensional model structure as properties and define degree addition as 'property addition'. For example, we can analyze the degrees denoted by *4000 ships* and *5000 ships* as the intensions of these nouns, that is, as functions which map every possible world to the sets of entities which consist of four thousand ships and five thousand ships, respectively; the degree addition then should yield the function which maps every possible world to the set of entities which consist of nine thousand ships. Then it suffices to assume that there are enough ships in at least **some** possible worlds. This, in turn unproblematic, as we would like to claim in any case that the intensions of, say, *9000 ships* and *10000 ships* is different, even in worlds in which there exist less than nine thousand ships. – To keep things simple, I will remain extensional here and assume that our model structures are always large enough to construct the degrees we need.

Now, we have to define an operation which takes the meaning of a verbal predicate like *pass through the lock* and yields a measure for events which represents the event-related reading. However, we cannot have a measure **function**, but only a measure **relation**, as the 'value' of the measure is not uniquely determined. For example, an event in which four thousand ships passed through the lock will be also an event in which four thousand watercraft passed through the lock, or maybe an event in which four thousand freight barges passed through the lock. So the 'value' of the measure can be either four thousand ships, four thousand watercraft, or four thousand freight barges, which clearly are different in the general case. Therefore we need relations, instead of functions. But even with measure relations we can proceed just as with the first approach, by

standardizing the measure relation in question with non-iterative events and generalize it by claiming additivity.

Call the new operation **OEMR**, for *O*bject-induced *E*vent *M*easure *R*elation. It takes an event relation and yields a relation between events and predicates which are quantized with respect to a lattice sort.

(24) Let Σ be a lattice sort and α an event relation. Then $\mathbf{OEMR}(\alpha)$ is defined as the smallest relation σ between an event and a quantized predicate of the lattice sort Σ such that (for any event e and quantized predicates β, β')

(i) (Standardization)

$$\neg\mathbf{ITER}(e, \alpha) \rightarrow [\sigma(e, \beta) \leftrightarrow \exists u[\beta(u) \wedge \alpha(e, u)]]$$

(ii) (Generalization)

$$\neg e \circ_{\Sigma} e' \wedge \sigma(e, \beta) \wedge \sigma(e', \beta') \rightarrow \sigma(e \cup_{\mathrm{E}} e', \beta +_{\Sigma} \beta')$$

Look at the derivation of the event-related reading of our standard example *four thousand ships passed through the lock*:

(25) *pass through the lock* [V/NP]
pass_through_the_lock′

| *four thousand ships* [N]
| $\lambda u[\mathbf{ship}'(u) = \mathbf{4000}]$
| | $\emptyset$[NP/N]
| | $\lambda \mathrm{P} \lambda \mathrm{R} \lambda e[\mathbf{OEMR}(\mathrm{R})(e, \mathrm{P})]$
| /
| *four thousand ships* [NP]
| $\lambda \mathrm{R} \lambda e[\mathbf{OEMR}(\mathrm{R})(e, \lambda u[\mathbf{ship}'(u) = \mathbf{4000}])]$
/

four thousand ships pass through the lock [V]
$\lambda e[\mathbf{OEMR}(\mathbf{pass\_through\_the\_lock}')(e, \lambda u[\mathbf{ship}'(u) = \mathbf{4000}])]$

Here we can take as a basis the normal syntactic structure. The only difference from the object-related reading is that the nominal predicate *four thousand ships* is combined with another determiner. The determiner has two functions: first, it builds up the desired measure relation for events, and second, it specifies the 'value' of this measure relation – which is specified by the nominal predicate.

According to (24), the object-induced measure relation for events in this example is the following one:

(26) **OEMR(pass_through_the_lock′)** is the smallest measure re-

lation σ such that, if $\mathbf{QUA_O}(\beta)$, $\mathbf{QUA_O}(\beta')$,
(i) (Standardization) $\neg\mathbf{ITER}(e, \mathbf{pass\_through\_the\_lock}')$
$\rightarrow [\sigma(e, \beta) \leftrightarrow \exists u[\mathbf{pass\_through\_the\_lock}'(e, u) \wedge \beta(u)]]$
(ii) (Generalization)
$\neg e \circ_E e' \wedge \sigma(e, \beta) \wedge \sigma(e', \beta') \rightarrow \sigma(e \cup_E e', \beta +_O \beta')$

If the first argument of σ is an event e which is non-iterative with respect to the relation **pass_through_the_lock'**, then β can specify the number of ships which passed through the lock in e. This can be derived via rule (i), standardization. If the first argument of σ is an iterative event with respect to **pass_through_the_lock'**, it is defined only if there is a partition of e into non-overlapping events $e_1, e_2, \ldots, e_m$ such that for any of these events, σ relates e to the quantized predicates $\beta_1, \beta_2, \ldots, \beta_m$ according to rule (i). By additivity, as claimed in rule (ii), σ then relates the join of the events $e_1, e_2, \ldots, e_m$ to the quantized predicate $\beta_1 +_O \beta_2 +_O \cdots +_O \beta_m$.

Cases with mass nouns, like *four thousand tons of radioactive waste passed through the lock*, can be treated exactly the same way:

(27) *sixty tons of radioactive waste passed through the lock*
$\lambda w[\mathbf{OEMR}(\mathbf{pass\_through\_the\_lock}')$
$(e, \lambda u[\mathbf{radioactive\_waste}'$-
$(u) \wedge \mathbf{ton}'(u) = \mathbf{60}])]$

Example. To get a fuller grasp of how the second approach works, we will again look at the passings through the lock by the ships Candida and Eleonore (cf. 13). We are looking for a value X which satisfies the following measure relation:

(28)a. $\mathbf{OEMR}(\mathbf{pass\_through\_the\_lock}'])(e_1 \cup_E e_2 \cup_E e_3, X)$

As $e_1 \cup_E e_2 \cup_E e_3$ is an iterative event with respect to the relation **pass_through_the_lock'**, we cannot employ the standardization clause directly. A partition into non-iterative parts is $e_1 \cup_E e_2$ and e_3. According to the standardization clause, we have

(28)b. $\mathbf{OEMR}(\mathbf{pass\_through\_the\_lock}')(e_1 \cup_E e_2, \lambda u[\mathbf{ship}'(u) = \mathbf{2}])$
c. $\mathbf{OEMR}(\mathbf{pass\_through\_the\_lock}')(e_3, \lambda u[\mathbf{ship}'(u) = \mathbf{1}])$

And by generalization, we have

(28)d. $\mathbf{OEMR}(\mathbf{pass\_through\_the\_lock}')(e_1 \cup_E e_2 \cup_E e_3, \lambda u[\mathbf{ship}'(u) = \mathbf{2}]$
$+_O \lambda u[\mathbf{ship}'(u) = \mathbf{1}])$

As $\lambda u[\mathbf{ship}'(u) = \mathbf{2}] +_O \lambda u[\mathbf{ship}'(u) = \mathbf{1}] = \lambda u[\mathbf{ship}'(u) = \mathbf{3}]$, this equals

(28)e. $\mathbf{OEMR}(\mathbf{pass\_through\_the\_lock}')(e_1 \cup_E e_2 \cup_E e_3, \lambda u[\mathbf{ship}'(u) =$
$\mathbf{3}])$

We see that $e_1 \cup_E e_2 \cup_E e_3$ is an event which falls under the event-related reading of *three ships passed through the lock*, according to the second approach.

To conclude this section, I want to point out an interesting phenomenon in the interpretation of sentences involving measure functions, which can be called **pragmatic maximalization** (cf. also Kadmon 1987). For example, the sentence *four thousand ships passed through the lock* (in its object-related or in its event-related reading) is literally true even if, actually, more than four thousand ships passed through the lock (in the object-related or in the event-related interpretation, respectively). However, we can at least pragmatically conclude that not more than four thousand ships passed through the lock. This phenomenon is a case of **scalar implicature** (cf. Horn 1972, Fauconnier 1978). As it occurs in both the object-related and the event-related interpretation, it is independent of the phenomenon we are concerned with here, and we will not go into it further.

4. Some further cases of event-related readings

4.1. *Coordinated Degrees*

As with our basic examples, we can distinguish between an object-related and an event-related reading with the following examples:

(29)a. Three thousand freight barges and one thousand yachts passed through the lock last year.

b. Fifty tons of uranium and ten tons of thorium passed through the lock last year.

How can we represent the event-related readings of these sentences? One way is to trace them back to coordinated sentences. For example, (29a) could be derived from the following coordinated sentence:

(30) Three thousand freight barges passed through the lock last year and one thousand yachts passed through the lock last year.

This could be done in the first approach by raising the number words, as in (21), and defining a coordination operation for semantic representations of type of $\lambda R \lambda e \Phi$, where Φ is a formula. Let S, S′ be variables of that type, then the coordination can be defined as

(31) $\lambda S \lambda S' \lambda R \lambda e \exists e' \exists e''[S(R)(e') \wedge S'(R)(e'') \wedge e = e' \cup_E e'']$

A less clumsy analysis is possible with the second approach. First, we have to define a conjunction for predicates based on the join operation. It can

be simply rendered as the predicate addition defined in (22). For example, the complex nominal predicate *three thousand freight barges and one thousand yachts* gets the following interpretation:

(32) $\lambda u[\mathbf{freight\_barge}'(u) = \mathbf{3000}] +_{\mathrm{O}} \lambda u[\mathbf{yacht}'(u) = \mathbf{1000}]$
$= \lambda u \exists u' \exists u''[\mathbf{freight\_barge}'(u') = \mathbf{3000} \wedge \mathbf{yacht}'(u'') = \mathbf{1000} \wedge$
$\neg u' \circ_{\mathrm{O}} u'' \wedge u = u' \cup_{\mathrm{O}} u'']$

This predicate applies to objects which consist of three thousand freight barges and one thousand yachts.

The predicate (32) can play the role of the predicate representing *four thousand ships* in the object-related reading and in the event-related reading. In the object-related reading, it simply applies to an object which consists of three thousand freight barges and one thousand yachts, and claims that such an object passed through the lock (cf. (33a)). In the event-related reading, it specifies the second argument of the induced event measure relation (cf. (33b)).

(33) *three thousand freight barges and one thousand yachts passed through the lock*

a. Object-related reading:
$\lambda e \exists u[\mathbf{pass\_through\_the\_lock}'(e, u) \wedge \exists u' \exists u''$
$[\mathbf{freight\_barge}'(u') = \mathbf{3000} \wedge$
$\mathbf{yacht}'(u'') = \mathbf{1000} \wedge \neg u' \circ_{\mathrm{O}} u'' \wedge u = u' \cup_{\mathrm{O}} u'']]$

b. Event-related reading:
$\lambda e[\mathbf{OEMR}(\lambda u \lambda e[\mathbf{pass\_through\_the\_lock}'(e, u)])$
$(e, \lambda u \exists u' \exists u''[\mathbf{freight\_barge}'(u') = \mathbf{3000}$
$\wedge \mathbf{yacht}'(u'') = \mathbf{1000} \wedge \neg u' \circ_{\mathrm{O}} u'' \wedge u = u' \cup_{\mathrm{O}} u'']))]$

In both cases, we get the right interpretations in a simple way.

4.2. *Comparison Constructions*

We find the object-related and the event-related reading also with comparison constructions, as the following examples show:

(23)a. More freight barges than yachts passed through the lock last year.

b. As many freight barges as yachts passed through the lock last year.

c. Too much radioactive waste passed through the lock last year.

Our analysis of the event-related reading is such that it is compatible with plausible analyses of comparison constructions. Here, I will concentrate on (34a).

Let us assume the theory of phrasal comparatives outlined in Heim (1985), together with the comparative semantics of Seuren (1973). In this theory, a sentence like (35a) is mapped to a semantic representation like (35b), where d is a degree variable. With the operator **COMP** interpreted as in (35c), we end up with the representation (35d).

(35)a. *Mary is taller than John*

b. $\mathbf{COMP}(\mathbf{Mary}', \mathbf{John}', \lambda u \lambda d[\mathbf{tall}'(u, d)])$

c. $\mathbf{COMP}(\mathrm{A}, \mathrm{B}, \mathrm{R}) \leftrightarrow \exists d[\mathrm{R}(\mathrm{A})(d) \wedge \neg \mathrm{R}(\mathrm{B})(d)]$

d. $\exists d[\mathbf{tall}'(\mathbf{Mary}', d) \wedge \neg \mathbf{tall}'(\mathbf{John}', d)]$

That is, the sentence *Mary is taller than John* is interpreted as 'Mary is tall to a degree to which John is not tall'. Now look at the interpretation of the event-related reading of (34a) in this framework:

(36) $$\begin{aligned}&\mathbf{COMP}(\mathbf{freight\_barge}', \mathbf{yacht}',\\ &\lambda \mathrm{R} \lambda n \exists e[\mathbf{OEMR}(\mathbf{pass\_through\_the\_lock}')(e, \lambda u \mathrm{R}(u, n))])\\ &=\\ &\exists n[\exists e[\mathbf{OEMR}(\mathbf{pass\_through\_the\_lock}')\\ &(e, \lambda u[\mathbf{freight\_barge}'(u) = n])] \wedge\\ &\neg \exists e[\mathbf{OEMR}(\mathbf{pass\_through\_the\_lock}')(e, \lambda u[\mathbf{yacht}'(u) = n])]]\end{aligned}$$

In prose: There is a number n such that n freight barges passed through the lock (in the event-related reading), but it is not the case that n yachts passed through the lock (in the event-related reading). This gives us the correct truth conditions of our example.

4.3. *Quantifiers*

We find event-related readings in cases with quantified NPs as well. Some examples:

(37)a. Most ships passed through the lock at night.

b. Every ship passed through the lock at night.

c. No ship passed through the lock at night.

Sentence (37a) can either mean that more than half of the ships (of a given domain of entities) passed through the lock during the night. Or it can mean that more than half of the lock traversals of a ship occurred at night. Similarly, sentence (37b) can either mean that every ship (of a given domain) passed through the lock during the night, or that every lock traversal of a ship occurred at night. We have also two readings for (37c): It can either mean that none of the ships (of a given domain) passed

through the lock at night, or that no lock traversal of a ship occurred at night.

Although the literature on quantification in natural language is quite large, it seems that the event-related readings of the examples (37) have escaped discovery until now. I will concentrate here on the first example, (37a); our treatment generalizes to the other examples. We will start with the treatment of its object-related interpretation. To relate the analysis to the standard theory of quantification as represented in the Generalized Quantifier theory (cf. Barwise and Cooper 1981), I will first propose a treatment which incorporates the event-semantic interpretation into the GQ framework.

First, we have to define a maximalization operation. Let **max**(P) be the maximal number n such that P(n) is true. The sign '÷' should denote arithmetical division, and R should be a variable of the type of count nouns. We represent the adverbial *at night* simply as an event predicate modifier.

Second, we have to think how we can treat quantified NPs similarly to the other NPs, that is, as something which, when combined with an event relation, yields an event predicate. Here I will take up the solution presented in Krifka (to appear). It is argued there that quantified sentences (and indeed, other sentences as well) must be interpreted with respect to a reference time. I introduced there an event predicate **MXT**, which applies to the maximal event of the reference time, that is, the event which contains every event which occurred during the reference time. (I suppress here the reference time index). With this predicate, we can treat quantifiers (and even negation) in event semantics.

Look at the following representation, a treatment of the object-related reading of our main example:

(38) *ships* [N/Nu]
$\lambda n \lambda u[\mathbf{ship}'(u) = n]$
|
most [NP/(N/Nu)]
$\lambda \mathrm{R}' \lambda \mathrm{R} \lambda e[\mathbf{MXT}(e) \wedge \mathbf{max}(\lambda n \exists u \exists e'[\mathrm{R}'(u, n) \wedge \mathrm{R}(e', u)$
$\wedge\ e' \subseteq_{\mathrm{E}} e]) \div \mathbf{max}(\lambda n \exists u[\mathrm{R}'(u, n)]) > \frac{1}{2}]$
/
most ships [NP]
$\lambda \mathrm{R} \lambda e[\mathbf{MXT}(e) \wedge \mathbf{max}(\lambda n \exists u \exists e'[\mathbf{ship}'(u) = n \wedge \mathrm{R}(e', u)$
$\wedge\ e' \subseteq_{\mathrm{E}} e]) \div \mathbf{max}(\lambda n \exists u[\mathbf{ship}'(u) = n]) > \frac{1}{2}]$
|

pass through the lock [V/NP]
pass_through_the_lock′

at night [V/V]
$\lambda R \lambda u \lambda e[R(e, u) \wedge \mathbf{at\_night}'(e)]$
/

pass through the lock at night [V/NP]
$\lambda u \lambda e[\mathbf{pass\_through\_the\_lock}'(e, u) \wedge \mathbf{at\_night}'(e)]$
/

most ships pass through the lock at night [V]
$\lambda e[\mathbf{MXT}(e) \wedge \mathbf{max}(\lambda n \exists u \exists e'[\mathbf{ship}'(u) = n$
$\wedge\ \mathbf{pass\_through\_the\_lock}'(e', u) \wedge$
$\mathbf{at\_night}'(e') \wedge e' \subseteq_{\mathrm{E}} e]) \div \mathbf{max}(\lambda n \exists u[\mathbf{ship}'(u) = n]) > \frac{1}{2}]$

We get an event predicate which applies to the maximal event (of the reference time) in case this event contains an event which is the passing of more than half of the ships. This event predicate can be transformed to a sentence by applying the declarative operator (see 14).

Example. To return to our little example, let us assume that in a maximal situation e_m the ship Candida passed the lock during the day (e_1), and the ship Eleonore passed the lock twice during the night (e_2, e_3). Let us, furthermore, assume that there are no other ships. Then we have:

(39)a. $\mathbf{max}(\lambda n \exists u \exists e'[\mathbf{ship}'(u) = n \wedge \mathbf{pass\_through\_the\_lock}'(e', u) \wedge \mathbf{at\_night}'(e)$
$\wedge\ e' \subseteq_{\mathrm{E}} e_m]) = \mathbf{1}$ (as $u = \mathbf{Eleonore}'$ yields the value 1)

b. $\mathbf{max}(\lambda n \exists u \exists e[\mathbf{ship}'(u) = n]) = \mathbf{2}$ (as $u = \mathbf{Candida}' \cup_{\mathrm{O}} \mathbf{Eleonore}'$ yields the value 2)

As it does not hold that $1 \div 2$ is greater than $\frac{1}{2}$, the predicate representing *most ships pass through the lock at night* does not apply to the maximal event e_m.

Now let us look at the event-related readings of our examples (37). One important fact is that the interpretation depends on which constituent is in focus, that is, bears sentence accent. This can be seen with the following minimal pair:

(40)a. Most books were lent out from counter A in the MORNINGS (rather than in the afternoons).

b. Most books were lent out in the mornings from COUNTER A (rather than from counter B).

In example (40a), it is said that most events of lending out a book from

counter A happened in the mornings. In (40b), it is said that most events of lending out a book in the mornings happened from counter A. These sentences clearly have different truth conditions, which can be traced back to different focus assignments (*in the mornings* in (40a), *from counter A* in (40b)).

In the most natural reading of (37a), the adverbial phrase *at night* is in focus, and it is said that most events of a ship passing through the lock happened at night (rather than at daytime), that is, that the ratio of ship passings at night to ship passings in general is greater than $\frac{1}{2}$.

To handle these readings, we have to decide how to represent the focus of an expression. Basically, we have two options: **structured semantic representations**, as developed by Cresswell and von Stechow (1982) and Jacobs (1983), or **semantic representations with alternatives**, as developed by Rooth (1985) (see v. Stechow 1988 for a survey). I will pursue a variant of the structured representation approach here.

In this approach, an expression with focus is represented as a pair of terms in the representation language such that one term represents the **background** and the other represents the **focus**. For technical reasons, I will represent structured semantic representations not as pairs, but as triples $\langle \beta, \alpha, a \rangle$, with β a semantic representation of the background with a free occurence of the variable a, and α a semantic representation of the focus, which is of the same type as the variable a. To get an impression of which representation I have in mind, look at the following example. P should be a variable of the type of predicate modifiers.

(41) *pass through the lock* [V/NP]
pass_through_the_lock′

at night [(V/NP)/(V/NP)]
$\lambda R \lambda u \lambda e[R(e, u) \wedge \mathbf{at\_night}'(e)]$
|
(focusation)
|
($_F$ *at NIGHT*) [(V/NP)/(V/NP)]
$\langle P, \lambda R \lambda u \lambda e[R(e, u) \wedge \mathbf{at\_night}'(e)], P \rangle$
/

pass through the lock ($_F$ *at NIGHT*) [V/NP]
$\langle P(\mathbf{pass\_through\_the\_lock}'), \lambda R \lambda u \lambda e[R(e, u) \wedge \mathbf{at\_night}'(e)], P \rangle$

a ship [NP]
$\lambda R \lambda e \exists u[R(e, u) \wedge \mathbf{ship}'(u) = \mathbf{1}]$
/

a ship pass through the lock ($_F$ *at NIGHT*) [V]

$\langle \lambda R \lambda e \exists u[R(e, u) \wedge \mathbf{ship}'(u) = \mathbf{1}](P(\mathbf{pass\_through\_the\_lock}')),$
$\lambda R \lambda u \lambda e[R(e, u) \wedge \mathbf{at\_night}'(e)], P\rangle$

I assume a process of focusation, which is marked by capitalization and indicated in the syntactic representation by brackets indexed with f. Semantically, focusation changes a basic semantic representation α into a structured semantic representation $\langle a, \alpha, a\rangle$, where a is a variable of the type of α. (That is, the background of a constituent in focus is simply a free occurence of the focus variable.) The rules for semantic composition with structured semantic representation can be given as follows: First, the semantic type of a structured representation $\langle \beta, \alpha, a\rangle$ is the semantic type of β. Second, semantic composition of a structured representation $\langle \beta, \alpha, a\rangle$ with an unstructured semantic representation γ, SEM(γ, $\langle \beta, \alpha, a\rangle$), is defined as $\langle$SEM(γ, β), α, $a\rangle$.

We can easily transform structured semantic representations into normal semantic representation. Let us assume that we have variables **R** ranging over structured representations, and projection operators **BC**, **FC** and **VR**, yielding the background, the focus and the variable of a structured representation, respectively. That is, we have $\mathbf{BC}(\langle \beta, \alpha, a\rangle) = \beta$, $\mathbf{FC}(\langle \beta, \alpha, a\rangle) = \alpha$, and $\mathbf{VR}(\langle \beta, \alpha, a\rangle) = a$. If γ is not structured, we simply define $\mathbf{BC}(\gamma) = \mathbf{FC}(\gamma) = \gamma$, and $\mathbf{VR}(\gamma)$ as the first variable of the type of γ not occurring free in γ. Then we can define a declarative operator which replaces all free occurences of the focus variable in the background by the focus constituent. This operator can be seen at work in the following example:

(42) *a ship pass through the lock* ($_F$ *at NIGHT*) [V]
$\langle \lambda R \lambda e \exists u[R(e, u) \wedge \mathbf{ship}'(u) = \mathbf{1}](P(\mathbf{pass\_through\_the\_lock}')),$
$\lambda R \lambda u \lambda e[R(e, u) \wedge \mathbf{at\_night}'(e)], P\rangle$

$\emptyset$ [V/V]
$\lambda \mathbf{R} \lambda \mathbf{VR}(\mathbf{R})[\mathbf{BC}(\mathbf{R})](\mathbf{FC}(\mathbf{R}))$
/

a ship pass through the lock ($_F$ *at NIGHT*) [V]
$\lambda P \lambda R \lambda e \exists u[R(e, u) \wedge \mathbf{ship}'(u) = 1]$
$(P(\mathbf{pass\_through\_the\_lock}'))(\lambda R \lambda u \lambda e[R(e, u) \wedge$
$\mathbf{at\_night}'(e)])$

$= \lambda R \lambda e \exists u[R(e, u) \wedge \mathbf{ship}'(u) = 1](\lambda R \lambda u \lambda e[R(e, u) \wedge$
$\mathbf{at\_night}'(e)](\mathbf{pass\_through\_the\_lock}'))$

$= \lambda e \exists u[\mathbf{pass\_through\_the\_lock}'(e, u) \wedge \mathbf{at\_night}'(e) \wedge$
$\mathbf{ship}'(u) = 1]$

Now we are ready to face the treatment of the event-related reading of (37a). It is based on the second approach of representing object-induced measure functions for events. We assume that the verbal predicate *pass through the lock* ($_{\mathrm{F}}$ *at NIGHT*) has a structured semantic representation. We assume that for any variable a of a type $\langle\tau, \tau\rangle$, $\mathbf{ID}(a)$ is the identity function for entities of the type τ. That is, if b is of type τ, then $\mathbf{ID}(a)(b) = b$. In the case of a variable R of type $\langle\langle e, e, t\rangle, \langle e, e, t\rangle\rangle$, we have $\mathbf{ID}(\mathrm{R}) = \lambda \mathrm{R} \lambda x \lambda y[\mathrm{R}(y, x)]$.

(43) *pass through the lock* ($_{\mathrm{F}}$ *at NIGHT*) [V/NP]
$\langle \mathrm{P}(\mathbf{pass\_through\_the\_lock}'), \lambda \mathrm{R} \lambda u \lambda e[\mathrm{R}(e, u) \wedge \mathbf{at\_night}'(e)], \mathrm{P}\rangle$

most [NP/(N/Nu)]
$\lambda \mathrm{R}' \lambda \mathbf{R} \lambda e[\mathbf{MXT}(e) \wedge \mathbf{max}(\lambda n \exists e'[\mathbf{OEMR}(\lambda \mathbf{VR}(\mathbf{R})\mathbf{BC}(\mathbf{R})$
$(\mathbf{FC}(\mathbf{R}))(e', \mathrm{R}'(n)) \wedge e' \subseteq_{\mathrm{E}} e]) \div$
$\mathbf{max}(\lambda n \exists e'[\mathbf{OEMR}(\lambda \mathbf{VR}(\mathbf{R})\mathbf{BC}(\mathbf{R})(\mathbf{ID}(\mathbf{VR}(\mathbf{R})))$
$(e', \mathrm{R}'(n)) \wedge e' \subseteq_{\mathrm{E}} e]) > \frac{1}{2}]$

ships [N/Nu]
$\lambda n \lambda u[\mathbf{ship}'(u) = n]$
/

most ships [NP]
$\lambda \mathbf{R} \lambda e[\mathbf{MXT}(e) \wedge \mathbf{max}(\lambda n \exists e'[\mathbf{OEMR}(\lambda \mathbf{VR}(\mathbf{R})\mathbf{BC}(\mathbf{R})(\mathbf{FC}(\mathbf{R}))$
$(e', \lambda u[\mathbf{ship}'(u) = n]) \wedge e' \subseteq_{\mathrm{E}} e]) \div$
$\mathbf{max}(\lambda n \exists e'[\mathbf{OEMR}(\lambda \mathbf{VR}(\mathbf{R})\mathbf{BC}(\mathbf{R})(\mathbf{ID}(\mathbf{VR}(\mathbf{R})))$
$(e', \lambda u[\mathbf{ship}'(u) = n]) \wedge e' \subseteq_{\mathrm{E}} e]) > \frac{1}{2}]$
/

most ships pass through the lock ($_{\mathrm{F}}$ *at NIGHT*) [V]
$\lambda e[\mathbf{MXT}(e) \wedge$
$\mathbf{max}(\lambda n \exists e'[\mathbf{OEMR}(\lambda \mathrm{PP}(\mathbf{pass\_through\_the\_lock}')$
$(\lambda \mathrm{R} \lambda u \lambda e[\mathrm{R}(e, u) \wedge \mathbf{at\_night}'(e)]))$
$(e', \lambda u[\mathbf{ship}'(u) = n]) \wedge e' \subseteq_{\mathrm{E}} e]) \div$
$\mathbf{max}(\lambda n \exists e'[\mathbf{OEMR}(\lambda \mathrm{PP}(\mathbf{pass\_through\_the\_lock}')$
$(\lambda \mathrm{R} \lambda x \lambda y[\mathrm{R}(y, x)]))(e', \lambda u[\mathbf{ship}'(u) = n]) \wedge e' \subseteq_{\mathrm{E}} e]) > \frac{1}{2}]$

$= \lambda e[\mathbf{MXT}(e) \wedge$
$\mathbf{max}(\lambda n \exists e'[\mathbf{OEMR}(\lambda u \lambda e[\mathbf{pass\_through\_the\_lock}'(e, u) \wedge$
$\mathbf{at\_night}'(e)])(e', \lambda u[\mathbf{ship}'(u) = n]) \wedge e' \subseteq_{\mathrm{E}} e]) \div$
$\mathbf{max}(\lambda n, \exists e'[\mathbf{OEMR}(\mathbf{pass\_through\_the\_lock}')(e', \lambda u[\mathbf{ship}'(u) =$
$n])) \wedge e' \subseteq_{\mathrm{E}} e]) > \frac{1}{2}]$

This predicate applies to maximal events e with the property that the proportion of the maximal number n such that n ships passed through the lock at night (event-related interpretation) in e to the maximal number n such that n ships passed through the lock (also event-related interpretation) in e is greater than $\frac{1}{2}$.

Note that *most ships* in this representation has properties of both a nominal and an adverbial quantifier. On the one hand, it combines with a noun and binds a syntactic argument of the verb. On the other hand, it is based on a relation between classes of events, just as *mostly* (or *always* or *never*) are. Furthermore, it needs a constituent in focus, which is typical for adverbial quantifiers as well (see the discussion of sentences like (*In Saint Petersburg*), *officers always escorted BALERINAS* vs. *OFFICERS always escorted balerinas* in Rooth 1985).

Example. To exemplify this treatment, look again at our little example. Now we have the following conditions:

(44)a. $\mathbf{max}(\lambda n \exists e'[\mathbf{OEMR}(\lambda u \lambda e[\mathbf{pass\_through\_the\_lock}'(e, u) \wedge \mathbf{at\_night}'(e)])(e', \lambda u[\mathbf{ship}'(u) = n]) \wedge e' \subseteq_{\mathrm{E}} e_m]) = \mathbf{2}$
(as $e' = e_2 \cup e_3$ yields the value $\lambda u[\mathbf{ship}'(u) = \mathbf{2}]$)

b. $\mathbf{max}(\lambda n \exists e'[\mathbf{OEMR}(\mathbf{pass\_through\_the\_lock}')(e', \lambda u[\mathbf{ship}'(u) = n]) \wedge e' \subseteq_{\mathrm{E}} e_m])\rangle = \mathbf{3}$
(as $e' = e_1 \cup_{\mathrm{E}} e_2 \cup_{\mathrm{E}} e_3$ yields the value $\lambda u[\mathbf{ship}'(u) = \mathbf{3}]$)

As $2 \div 3 > \frac{1}{2}$, we have the result that the event predicate *most ships pass through the lock* ($_{\mathrm{F}}$ *at NIGHT*) applies to the maximal event e_{m}.

In principle, we can handle cases with mass nouns like the following ones along similar lines:

(45)a. Most radioactive waste passed through the lock at night.
b. All radioactive waste passed through the lock at night.
c. No radioactive waste passed through the lock at night.

However, we cannot simply rely on numbers to determine the proportions in these cases. This holds even for the object-related reading. Instead, we must invoke some appropriate dimension (for example weight, or volume; cf. Cresswell, 1976). I will not go into this separate problem here.

4.4. *Problems of Anaphora*

In this section, I want to point out a problem with anaphora and sentences with event-related readings and hint at a possible solution. The problem

occurs, for example, in the following texts:

(46)a. Four thousand ships passed through the lock last year. *They* transported radioactive waste.

b. Sixty tons of radioactive waste was transported through the lock last year. *It* was declared as powdered sugar.

Take the first example, which is representative of both. Note that the first sentence can have an object-related or an event-related interpretation in this text. The problem is to account for the event-related interpretation, as we cannot assume that the first sentence directly introduces an object which is four thousand ships such that the pronoun can refer to that object.

I propose to treat cases like these as follows: *They* in (46a) does not refer to an entity which is overtly introduced in the preceding sentence. Instead, it refers to an entity which is conventionally related to an entity which is introduced in the preceding sentence. That is, I analyze it similar to the following case, where the definite NP *the windshield* refers to an entity which is conventionally related to the car, which is introduced in the first sentence:

(47) There was an old car standing in front of the house. *The windshield* was broken.

In the case of (46a), the first sentence in the event-related reading introduces an event *e* of ships passing through the lock. We can assume that, just as windshields are conventionally related to cars, ships are conventionally related to events of ships passing through the lock. The NP *they* in the second sentence, then, refers to the ships related to *e*, just as the NP *the windshield* in (47) refers to the windshield of the car. Of course, we would have to explain in the case of (46a) why we can refer with a pronoun (as opposed to a full NP) to an entity which is not introduced directly. I will argue that although the ships themselves are not directly introduced in the first sentence of (46a), the **concept** of ships is introduced, and that pronouns can pick up concepts. However, I have to defer the detailed argumentation to Krifka (in prep.).

4.5. *Phase Nouns*

Finally, we will return to phase nouns like *passenger*, *batter*, and the like. Let us look at a variant of Gupta's example:

(48)a. Two million passengers were served by National Airlines in 1975.

b. Two million persons were served by National Airlines in 1975.

Example (48b) has two readings (object-related and event-related), whereas (48a) seems to have only one which is similar to the event-related reading of (48b). How can we explain this?

I think the best way to do so is to assume that (48a) indeed has two readings as well, but that they have the same truth conditions. The reason for that can be sketched as follows: Let us assume the analysis of Carlson (1982) that phase nouns like *passenger* apply to temporal parts of entities to which normal nouns like *person* apply. (These entities might be construed as pairs of ordinary entities and time intervals). In the case at hand, we can analyze *passenger* as a measure function compatible with some lattice sort which yields the value 1 if applied to one person-during-a-single-event-of-transportation. As a passenger can be defined with respect to single events of transportations (at least in one possible reading of *passenger*), it cannot possibly stand in an iterative relation with respect to an event of transportation. Or, to put it in another way: one passenger is subjected to one event of transportation exactly one time. But then both ways of measuring – by counting the passengers, or by counting non-iterative acts of transportations of one passenger – necessarily yield the same results.

If we consider other events than those which play a role in the definition of phase nouns, ordinary nouns and phase nouns should behave similarly. For example, the following sentences each have an object-oriented and an event-oriented reading which differ in their truth conditions (remember that one passenger can be served more than one hot meal during a flight):

(49)a. Three million passengers were served a hot meal by National Airways in 1975.

b. Three million persons were served a hot meal by National Airways in 1975.

One could say that phase nouns represent the reverse direction of the induction of measurement functions we have considered so far. In the event-related interpretation, we derive a measure function for events from a measure function for objects (and an event relation). With phase nouns, we derive a measure function for objects from a measure function for events.

5. Conclusion

We have seen that it is possible to give a semantic analysis of event-related meanings of the sentences in (1) in terms of measure functions (or relations) on events which are induced by the measure functions on ob-

jects. Furthermore, I hope to have shown that the solution does not break down when we consider more complex cases, such as coordination, quantification, comparison, and anaphora.

There are many more examples which show that the derivation of one measure from another measure is by no means an isolated phenomenon. I will end by giving three cases which can be handled similarly.

The first case is **container measures**, as in the following constructions:

(50)a. fifty bottles of wine
b. five spoonfuls of honey

Here, we can assume that the measure nouns *bottle* and *spoon* are measure functions on objects, namely, bottles or spoons. Furthermore, the notion of objects x contained in other objects y can be captured by a function which maps x to its container y. Then it is easy to define a measure function for the contained objects which is induced by the measure functions for the containers. The standardization scheme in the case of *bottle* is that some object x measures n bottles if there is an object y which consists of n bottles and which x completely fills up. The generalization scheme could generalize this measure to objects x which do not completely fill up their containers or which even are not contained at all (for example, we can say that a certain amount of wine measures 5 bottles although it is not actually contained in bottles). In the case of *spoonful*, the suffixation of *-ful* is a morphological indication for this process of deriving one measure function from another via the mapping of entities to their containers.

The second case consists of distance expressions with movement verbs, as in the following example:

(51) walk ten kilometers

A first approach to these sentences might say that the predicate *walk ten kilometers* applies to walking events whose starts and ends are ten kilometers apart. But in the case of walking in curves or circles, this simple procedure does not work. A way of handling these cases is to construct a measure function for movement events from a measure function for distances which makes use of the mapping of movement events to distances. This measure function can be standardized by linear moving events (for them, we have only to measure the distance between the start and the end), and it can be generalized by claiming additivity for any moving events (that is, if e is a moving event of 6 kilometers and e' is a moving event of 4 kilometers, and e and e' do not overlap, then $e \cup_E e'$ is a moving event of 10 kilometers, even if the start and the end of $e \cup_E e'$ is less than 10 km apart).

A third case can be found in the following example. Here, *fatalities* provides us with a measure for time. This measure can be derived by mapping fatalities to the time axis.

(52) Only two hundred fatalities later did the senate of Hamburg take any measures to hinder the cholera epidemic.

These are only some examples which show the remarkable ease we have in transferring measure functions from one domain to another. An explanation of that ease could be the existence of a separate and flexible module in our cognitive system which is specialized for gradation and measurement (cf. Bierwisch, 1987). In this article, then, I have tried to investigate some of the ways in which this module interacts with other semantic capabilities.

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