

## Event-related relative measurement<sup>1</sup>

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**Abstract.** This paper is concerned with relative measurement, which is expressed by percentage nouns and fractions. It has been observed that in some languages a sentence with relative measurement is ambiguous between two readings. I argue that these two readings involve two types of measurement—individual-related measurement and event-related measurement. I also provide a compositional analysis for the ambiguity of relative measurement. My analysis is able to capture many intriguing contrasts between the two readings of relative measurement, including those related to counting recycled individuals, compatibility with verbal affixes, structural distribution and scope.

**Keywords:** Relative measurement, measure function, event-individual pairs, event semantics

### 1. Introduction

One of the important properties of natural language is its capacity to express measurement. There are two kinds of measurement: absolute measurement, which is expressed by words such as *liter* and *inch*, and relative measurement, which is expressed by a class of measure items such as proportional nouns like *percent* and fractions like *thirds*. The former type of measurement has received a lot of attention in the semantic literature, while the latter has not until a series of works by Sauerland and Ahn (Sauerland 2014; Ahn and Sauerland 2015a, b, 2017). Unlike absolute measurement, relative measurement concerns the relation between two amounts. For example, in (1), relative measurement is expressed by the relative measure phrase, which consists of the relative measure item *30%* and the nominal phrase *the locals*. This sentence expresses that the local employees at Lenovo made up 30% of all the locals given in the context.

(1) Lenovo hired [30% of the locals].

Beyond the basic pattern, Ahn and Sauerland notice that English has another relative measurement construction, as exemplified in (2). Structurally, this sentence differs from (1) in not having the partitive *of* and the definite determiner, while semantically, it targets a different quantity relation. What this sentence means is that the local employees at Lenovo made up 30% of all the employees at Lenovo. It can be paraphrased as ‘30% of the people hired by Lenovo were locals.’

(2) Lenovo hired 30% locals.

In some languages, like Mandarin, these two interpretations arise from a single surface structure, as shown in (3).

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- (3) Lianxiang gu-le 30% de bendiren  
 Lenovo hire-ASP 30% DE locals
- a. ‘Lenovo hired 30% of the locals.’ (NP-internal)  
 $\Rightarrow |\{x : \mathbf{locals}(x) \wedge \mathbf{Lenovo-hired}(x)\}| = 30\% \times |\{y : \mathbf{locals}(y)\}|$
- b. ‘Lenovo hired 30% locals’ (NP-external)  
 $\Rightarrow |\{x : \mathbf{locals}(x) \wedge \mathbf{Lenovo-hired}(x)\}| = 30\% \times |\{y : \mathbf{Lenovo hired}(y)\}|$

Here, *30% de bendiren* ‘30% locals’ is a noun phrase. In reading (3a), the amount of local employees at Lenovo is measured relative to the set of all locals, which is provided by the NP complement. I call it the ‘NP-internal’ reading. In reading (3b), the amount of local employees at Lenovo is measured relative to the set of all the people hired by Lenovo, which is provided by the NP-external material, i.e., *Lianxiang gu-le* ‘Lenovo hired.’ I call it the ‘NP-external’ reading.

Intuitively, the NP-internal reading in (3a) expresses a quantity relation between two sets of locals—the set of locals hired by Lenovo and the set of all locals; whereas the NP-external reading in (3b) expresses a quantity relation between two sets of event participants—the set of theme participants of some hiring events who are locals and the set of all theme participants of some hiring events. Following this intuition, I argue that the NP-internal reading differs from the NP-external reading essentially in their domains of measurement: the former involves measurement of individuals, while the latter involves measurement of event-individual pairs, whose ontological status is considered to be stages of individuals (Barker 1999, 2010). (For example, if John dances twice, he participates in two non-overlapping dancing events  $e_1$  and  $e_2$ . The event-individual pairs  $\langle e_1, \mathbf{John} \rangle$  and  $\langle e_2, \mathbf{John} \rangle$  stand for two stages of John).

This claim is based on the observation that although the two readings seem to measure individuals, only the NP-external reading shows event-related properties (Section 2). I propose that there are two kinds of relative measure heads: one implements measurement on a domain of individuals, while another encodes measurement on a domain of event-individual pairs. These two relative measure heads essentially give rise to the NP-internal reading and the NP-external reading (Section 3). I also show that these two readings can be compositionally derived (Section 3.2). My analysis is able to account for a series of contrasts between the NP-internal reading and the NP-external reading, which involve a structural constraint on the NP-external reading (Section 4), the monotonicity condition of measure functions (Section 5) and scope patterns of relative measure phrases (Section 6). Finally, I compare my analysis with the focus mapping approach to relative measurement proposed by Ahn and Sauerland (Sauerland 2014; Ahn and Sauerland 2015a, b) (Section 7).

## 2. Counting recycled individuals

Let’s consider the following scenario. Town A has a population of 10,000, among which 2,000 are children. In the past quarter, a clinic in the town had 5,000 visits by 2,000 different patients. Among the 5,000 visits there were 1,500 visits by 500 different children. In the quarterly business meeting, if the administrator of the clinic states (4), the statement is inaccurate. Instead, if she states (5), the statement is accurate.

- (4) Women zhe yi jidu shouzhi-le quanzheng 30% de ertong.  
 we this one quarter treat-ASP whole.town 30% DE children  
 ‘We treated 30% of the children in the town this quarter.’ (NP-internal)
- (5) Women zhe yi jidu shouzhi-le 30% de ertong.  
 we this one quarter treat-ASP 30% DE children  
 a. ‘We treated 30% of the children (in the town) this quarter.’ (NP-internal)  
 b. ‘We treated 30% children this quarter.’ (NP-external)

Due to the explicit mentioning of the town, which helps to fix the domain of the children, (4) only has an NP-internal reading. It is clear why (4) is false: the number of children treated in the clinic is 500 but the total child population in the town is 2,000, so 30% is not an accurate proportion to report.

(5) is ambiguous between an NP-internal reading and an NP-external reading. As we know that the NP-internal reading is false, the truth judgment must come from the NP-external reading. However, only under a specific circumstance may the NP-external reading give rise to a true statement—a single individual can be counted more than once if she makes more than one visit. To see this, note that if we merely count the number of child patients (i.e., 500) relative to the number of total patients (i.e., 2,000), we get 25% instead of 30%. However, if we count the number of child visits (i.e., 1,500) relative to the number of total visits (i.e., 5,000), we get 30%. In short, the truth of (5) tells us that the NP-external reading allows counting recycled individuals.

The possibility of counting recycled individuals should remind us of Krifka’s (1990) famous example in (6). This sentence is argued to have two interpretations. The first one is an object-related interpretation and the second one is an event-related interpretation, as paraphrased in (6a) and (6b), respectively. If a certain ship passed through the lock twice, it is counted once in the first reading and twice in the second reading.

- (6) Four thousand ships passed through the lock last night.  
 a. There were 4000 ships such that they passed through the lock. (Object-related)  
 b. There were 4000 events such that in each of them a ship passed through the lock.  
 (Event-related)

Since Krifka (1990), various proposals have been defended to account for the ambiguity of (6), such as Moore (1994), Doetjes and Honcoop (1997) and Barker (1999). These proposals share the core idea that recycled individuals are counted by relation to events. The fact that the NP-external reading allows the counting of recycled individuals suggests that this reading should, too, be event-related.

To see that counting recycled individuals is indeed readily compatible with the NP-external reading of relative measurement and hence is not an artifact of Scenario 1, it is worthwhile to consider more examples:

- (7) Women *jiudian qunian jiedai-le 30% de gaoguan.*  
 we hotel last.year serve-ASP 30% DE high-ranking.officials  
 a. ‘Last year, our hotel served 30% of the high-ranking officials.’ (NP-internal)  
 b. ‘Last year, our hotel served 30% high-ranking officials.’ (NP-external)
- (8) Women *tushuguan qunian jiechu-le 70% de xiaoshuo.*  
 we library last.year lend.out-ASP 70% DE novel  
 a. ‘Last year, our library lent out 70% of the novels.’ (NP-internal)  
 b. ‘Last year, our library lent out 70% novels.’ (NP-external)

In these sentences, the identities of the individuals being talked about are irrelevant and easy to ignore in the NP-external reading. In (7), if some high-ranking officials stayed in our hotel twice, each of them could only be counted once in the NP-internal reading, but each of them was counted twice in the NP-external reading. In (8), the same contrast can be observed between the NP-internal reading and the NP-external reading, if some novels were lent out more than once.

### 3. Proposal

In this paper, I propose that relative measurement generally measures the size of one set relative to another, but the members of the sets can be **individual objects** or **event-related stages** of individuals. Measuring individuals yields the NP-internal reading, while measuring event-related stages results in the NP-external reading. Ontologically, an event-related stage can be understood as an instance of an individual object that participates in a specific event (see also Barker 1999, 2010). Following Barker (1999), I model event-related stages as event-individual pairs  $\langle e, x \rangle$  associating an individual  $x$  with an event  $e$ . As a first approximation, the two readings of (9) can be represented as (9a) and (9b).

- (9) Lianxiang *gu-le 30% de bendiren.*  
 Lenovo hire-ASP 30% DE local
- a. NP-internal:  $|\{x : \mathbf{locals}(x) \wedge \mathbf{Lenovo-hired}(x)\}| = 30\% \times |\{y : \mathbf{locals}(y)\}|$   
 (The individuals  $x$  such that  $x$  are locals and hired by Lenovo made up 30% of the locals)
- b. NP-external:  $|\{\langle e, x \rangle : \mathbf{locals}(x) \wedge \mathbf{Lenovo-hired}(e, x)\}|$   
 $= 30\% \times |\{\langle e', x' \rangle : \mathbf{Lenovo-hired}(e', x')\}|$   
 (The event-related stages  $\langle e, x \rangle$  such that  $x$  are locals and were hired by Lenovo in  $e$  made up 30% of the event-related stages  $\langle e', x' \rangle$  such that  $x'$  were hired by Lenovo in  $e'$ )

In the following subsections, I lay out the formal details of my proposal, showing how the two readings are compositionally derived.

### 3.1. Two relative measure heads

I propose that a relative measure item is decomposed into two parts—a percentage number and a relative measure head (RM). The former simply denotes a number of type  $d$  and the latter encodes measurement, which can be individual-related or event-related. I define the individual-related RM ( $RM_I$ ) and the event-related RM ( $RM_E$ ) as follows:

$$(10) \quad \llbracket RM_I \rrbracket = \lambda n_d \lambda P_{et} \lambda Q_{et}. \exists x. P(x) \wedge Q(x) \wedge \mathbf{card}(x) = n \times \mathbf{max} \left( \lambda n' \exists x' \left[ \begin{array}{l} P(x') \wedge \\ \mathbf{card}(x') = n' \end{array} \right] \right)$$

$$(11) \quad \llbracket RM_E \rrbracket = \lambda n'_d \lambda P_{et} \lambda T_{\langle e, \langle e, vt \rangle \rangle} \lambda y_e \lambda e''_v. \mathbf{MXT}(e'') \wedge \\ \exists \langle e, x \rangle. e \sqsubseteq e'' \wedge T(e, y, x) \wedge P(x) \wedge \mathbf{card}'_{\lambda z \lambda e''' . T(e''', y, z)}(e, x) = \\ n \times \mathbf{max} \left( \lambda n' \exists \langle e', x' \rangle \left[ \begin{array}{l} e' \sqsubseteq e'' \wedge R(e', y, x') \wedge \\ \mathbf{card}'_{\lambda z \lambda e''' . T(e''', y, z)}(e', x') = n' \end{array} \right] \right)$$

A note on notation: **max** and **MXT** stand for a maximal operator on degrees and a maximal operator on events, respectively. The former takes a set of degrees and returns the biggest element in this set, while the latter applies to maximal events consisting of the sum of all smaller events within a given time interval. They are defined as follows:

$$(12) \quad \begin{array}{ll} \text{a. } \mathbf{max}(D) := \iota n [D(n) \wedge \forall n' [D(n') \rightarrow n' \leq n]] \\ \text{b. } \mathbf{MXT}(e) := \exists t. e = \bigoplus (\lambda e' [\tau(e') \sqsubseteq t]) \end{array} \quad (\text{Krifka 1989})$$

In (10),  $RM_I$  introduces a measure function **card** (cardinality) on the domain of individuals. In this paper, I use the term *measure function* to denote a mapping from a class of entities to a degree scale that preserves an ordering relation, such as “be taller than” or “be heavier than.” Examples of typical measure functions are height, weight, and temperature. Following Krifka (1998), we define **card** as a function mapping individual entities to natural numbers.

In (11),  $RM_E$  introduces a measure function **card'** on the domain of event-individual pairs. In this study, I follow Doetjes and Honcoop's (1997) definition of measure functions on event-individual pairs. Adopting the algebraic semantic approach (Krifka 1989, 1990), Doetjes and Honcoop identify the domain of event-individual pairs as a join semi-lattice on the basis of the join semi-lattice structure of the domain of events. Then, the partial ordering on ordered event-individual pairs can be defined as (13) in terms of the partial ordering of events and the partial ordering of individuals.

$$(13) \quad \begin{array}{ll} \text{a. } \langle e, x \rangle \sqsubseteq \langle e', x' \rangle \leftrightarrow \langle e, x \rangle \oplus \langle e', x' \rangle = \langle e', x' \rangle \\ \text{b. } \langle e, x \rangle \oplus \langle e', x' \rangle = \langle e'', x'' \rangle \leftrightarrow e \oplus e' = e'' \wedge x \oplus x' = x'' \end{array}$$

Based on this algebraic structure, they implement Krifka's (1990) proposal on the measurement of events. The main idea that their implementation relies on is that the measure function **card'** on event-individual pairs can be standardized with respect to its corresponding measure function **card** on individuals. Take children-treating events as an example. If every child is treated once, measuring the  $\langle e, x \rangle$  pairs such that  $x$  is a child and  $x$  is treated in  $e$  yields the same value

as measuring children that are treated. In this case, different children are involved in different events. As a consequence, if there are  $n$  different children, there are the same number of pairs of treating events and children.

However, there is a problem: if some children were treated more than once, the equivalence of the pair measurement and the object measurement does not hold. In this case, the relation on treating children has the aspectual property of iterativity as defined below (Krifka 1989; Doetjes and Honcoop 1997):

- (14) **Definition (Iterativity (ITER))** For any event  $e$ , object  $x$  and relation  $R$ ,  
 $\text{ITER}(e, x, R) \leftrightarrow R(e, x) \wedge \exists e' \exists e'' \exists x' [e' \sqsubseteq e \wedge e'' \sqsubseteq e \wedge e' \neq e'' \wedge x' \sqsubseteq x \wedge R(e', x') \wedge R(e'', x')]$   
 (a relation  $R$  is iterative with respect to an event  $e$  and an object  $x$  just in case there is a part of  $x$  which is involved in different parts of  $e$ , as specified by  $R$ )

It does not mean that standardizing one measure function with respect to another cannot work in this case. On the basis of the fact that every iterative event can be partitioned into non-iterative subevents, Krifka (1990) proposes that an iterative event  $e$  can be correctly counted by dividing  $e$  into non-iterative subevents, applying a measure function on events to each non-iterative subevent, and adding all the values of the non-iterative subevents together. Following the spirit of this proposal, Doetjes and Honcoop define a measure function on  $\langle e, x \rangle$  in terms of its corresponding measure function on objects. Based on their study, I define the measure function on event-individual pairs as (15).

- (15) Let  $\mu$  be a measure function and  $R$  be an event-individual relation. Then the object induced event-individual pair measure function  $\mu'_R$  can be defined as follows:  
 $\mu'_R =$  the event-individual pair measure function  $\mu'$  with the smallest domain such that  
 a. **Standardization** For any event  $e$ , individual  $x$  and relation  $R$ ,  
 $[\neg \text{ITER}(e, x, R) \wedge R(e, x)] \rightarrow [\mu'(e, x) = n \leftrightarrow \mu(x) = n]$   
 b. **Generalization** For any events  $e$  and  $e'$ , and any individuals  $x$  and  $x'$ ,  
 $[\neg \langle e, x \rangle \circ \langle e', x' \rangle \wedge \mu'(e, x) = n \wedge \mu'(e', x') = n'] \rightarrow [\mu'(\langle e, x \rangle \oplus \langle e', x' \rangle) = n + n']$   
 Here,  $\circ$  stands for ‘overlapping’ and  $\langle e, x \rangle \circ \langle e', x' \rangle \leftrightarrow e \circ e' \wedge x \circ x'$

Consider a toy scenario. Three children  $C_1$ ,  $C_2$  and  $C_3$  are involved in three treating events  $e_1$ ,  $e_2$  and  $e_3$ , respectively. Additionally,  $C_1$  is treated a second time, so it is also involved in a fourth treating event  $e_4$ . Therefore, the pair  $\langle e_1 \oplus e_2 \oplus e_3 \oplus e_4, C_1 \oplus C_2 \oplus C_3 \rangle$  is in the relation of children-treating. Standardization can partition the pair into two parts  $\langle e_1 \oplus e_2 \oplus e_3, C_1 \oplus C_2 \oplus C_3 \rangle$  and  $\langle e_4, C_1 \rangle$ . Then, the measure function  $\mu'$  yields the value 3 for  $\langle e_1 \oplus e_2 \oplus e_3, C_1 \oplus C_2 \oplus C_3 \rangle$ , and the value 1 for  $\langle e_4, C_1 \rangle$ . Generalization adds up the two values to 4. The result is as if  $C_1$  is counted twice. Thus,  $\mu'$  provides an explicit way to count recycled individuals described in Section 2.

## 3.2. Composition

Recall example (3) in the first section, repeated here as (16). According to the proposal discussed in the previous section, the relative measure item *30%* consists of a percentage number and a null relative measure head, which can be  $RM_I$  or  $RM_E$ .

- (16) Lianxiang gu-le 30% de bendiren  
 Lenovo hire-ASP 30% DE locals  
 a. ‘Lenovo hired 30% of the locals.’ (NP-internal)  
 b. ‘Lenovo hired 30% locals.’ (NP-external)

I define the relevant lexical entries in the following table:

Item	Translation	Type
<i>Lianxiang</i> ‘Lenovo’	<b>Lenovo</b>	e
30%	30%	d
<i>bendiren</i> ‘locals’	$\lambda x.*\mathbf{local}(x)$	et
<i>de</i>	$\lambda x.x$	$\langle \alpha, \alpha \rangle$
EC	$\lambda V \exists e.V(e)$	$\langle vt, t \rangle$
<i>gu</i> ‘hire’	$\lambda x \lambda y \lambda e.*\mathbf{hire}(e) \wedge *\mathbf{th}(e) = x \wedge *\mathbf{ag}(e) = y$	$\langle e, \langle e, vt \rangle \rangle$
$RM_I$	see (10)	$\langle d, \langle et, \langle et, t \rangle \rangle \rangle$
$RM_E$	see (11)	$\langle d, \langle et, \langle \langle e, \langle e, vt \rangle \rangle, \langle e, vt \rangle \rangle \rangle \rangle$

In event semantics, a transitive verb is assumed to have three arguments—two individual arguments and one event argument (Krifka 1998; Landman 2000). The individual arguments serve as the agent (**ag**) and the theme (**th**) of the event. The event argument is bound by an existential closure operator (EC) at the sentential level. Additionally, I assume that not only plural nouns but also event predicates and thematic roles are closed under sum, which is indicated by the \*-operator (Landman 2000; Kratzer 2007; Champollion 2010).

In Mandarin, the particle *de* is often used as a modification marker, but it can also be used in measurement constructions, as in (17). Its status is not clear in these measurement constructions (Cheng and Sybesma 2009; Li and Rothstein 2012; a.o.). In this paper, I simply assume that the particle *de* is a type-neutral identity function, which passes up the meaning of a constituent that combines with it.

- (17) san-bang de rou                      suoyou de xuesheng  
 three-pound DE meat                    all DE student  
 ‘three pounds of meat’                ‘all of the students’

Let’s consider the NP-external reading first. The object relative measure phrase is composed via Functional Application (FA), as illustrated in (18).

$$(18) \quad \llbracket de \rrbracket (\llbracket RM_E \rrbracket (\llbracket 30\% \rrbracket)) (\llbracket locals \rrbracket) \xrightarrow{FA} \\ \lambda T \lambda y \lambda e'' . \mathbf{MXT}(e'') \wedge \\ \exists \langle e, x \rangle . e \sqsubseteq e'' \wedge T(e, y, x) \wedge *local(x) \wedge \mathbf{card}'_{\lambda z \lambda e''' . T(e''', y, z)}(e, x) = \\ 30\% \times \mathbf{max} \left( \lambda n' \exists \langle e', x' \rangle \left[ \begin{array}{l} e' \sqsubseteq e'' \wedge R(e', y, x') \wedge \\ \mathbf{card}'_{\lambda z \lambda e''' . T(e''', y, z)}(e', x') = n' \end{array} \right] \right)$$

As a result, the relative measure phrase denotes a function of type  $\langle \langle e, \langle e, vt \rangle \rangle, \langle e, vt \rangle \rangle$ . It maps the set characterized by a transitive verb, i.e., a set of  $\langle e, y, x \rangle$  sequences, to the set characterized by a verb phrase, i.e., a set of  $\langle e, y \rangle$  sequences.

$$(19) \quad \text{a.} \quad \llbracket 30\% RM_E de locals \rrbracket (\llbracket hire \rrbracket) \xrightarrow{FA} \\ \lambda y \lambda e'' . \mathbf{MXT}(e'') \wedge \exists \langle e, x \rangle . e \sqsubseteq e'' \wedge \\ \llbracket hire \rrbracket(e, y, x) \wedge *local(x) \wedge \mathbf{card}'_{\lambda z \lambda e''' . \llbracket hire \rrbracket(e''', y, z)}(e, x) = \\ 30\% \times \mathbf{max} \left( \lambda n' \exists \langle e', x' \rangle \left[ \begin{array}{l} e' \sqsubseteq e'' \wedge \llbracket hire \rrbracket(e', y, x') \wedge \\ \mathbf{card}'_{\lambda z \lambda e''' . \llbracket hire \rrbracket(e''', y, z)}(e', x') = n' \end{array} \right] \right)$$

$$\text{b.} \quad \llbracket EC \rrbracket (\llbracket hire 30\% RM_E de locals \rrbracket (\llbracket Lenovo \rrbracket)) \xrightarrow{FA} \\ \exists e'' . \mathbf{MXT}(e'') \wedge \exists \langle e, x \rangle . e \sqsubseteq e'' \wedge \\ \llbracket hire \rrbracket(e, \mathbf{l}, x) \wedge *local(x) \wedge \mathbf{card}'_{\lambda z \lambda e''' . \llbracket hire \rrbracket(e''', \mathbf{l}, z)}(e, x) = \\ 30\% \times \mathbf{max} \left( \lambda n' \exists \langle e', x' \rangle \left[ \begin{array}{l} e' \sqsubseteq e'' \wedge \llbracket hire \rrbracket(e', \mathbf{l}, x') \wedge \\ \mathbf{card}'_{\lambda z \lambda e''' . \llbracket hire \rrbracket(e''', \mathbf{l}, z)}(e', x') = n' \end{array} \right] \right)$$

(19b) says: there is a maximal event within a specific time interval; the maximal event contains hiring subevents whose agents are Lenovo and whose themes are locals; the measure function  $\mathbf{card}'_{\lambda z \lambda e''' . \llbracket hire \rrbracket(e''', \mathbf{l}, z)}$  applies to the theme participants of these events, which are stages of individuals participating in these hiring events. The result is equal to 30% times the maximal number of the theme participants of the events of Lenovo's hiring.

Turning to the NP-internal reading, the object relative measure phrase in (16) denotes a generalized quantifier of type  $\langle et, t \rangle$ , as illustrated by the following compositional process.

$$(20) \quad \llbracket de \rrbracket (\llbracket RM_I \rrbracket (\llbracket 30\% \rrbracket)) (\llbracket locals \rrbracket) \xrightarrow{FA} \\ \lambda Q \exists x . *local(x) \wedge Q(x) \wedge \mathbf{card}(x) = 30\% \times \mathbf{max} \left( \lambda n' \exists x' \left[ \begin{array}{l} *local(x') \wedge \\ \mathbf{card}(x') = n' \end{array} \right] \right)$$

Hence, we can compose the relative measure phrase with the rest of the sentence by Quantifier Raising, as shown in (21).

$$(21) \quad \llbracket 30\% \text{ RM}_I \text{ de locals} \rrbracket (\lambda x. \llbracket [\text{EC} [\text{Lenovo hire } t_1]] \rrbracket^{g[1/x]}) \stackrel{\text{FA}}{\Rightarrow} \\ \exists x \exists e. * \mathbf{local}(x) \wedge \llbracket \text{hire} \rrbracket(e, \mathbf{l}, x) \wedge \mathbf{card}(x) = 30\% \times \mathbf{max} \left( \lambda n' \exists x' \left[ \begin{array}{l} * \mathbf{local}(x') \wedge \\ \mathbf{card}(x') = n' \end{array} \right] \right)$$

(21) says: there are locals hired by Lenovo; the measure function  $\mathbf{card}(x)$  applies to them and the result is equal to 30% times the maximal number of locals.

According to my proposal, the NP-external reading involves the measure function on event-individual pairs. As we have presented in Section 3.1, the measure function counts recycled individuals more than once. By contrast, the NP-internal reading involves the measure function on individuals. Therefore, when an individual participates in an event twice, it can only be counted once. This is the reason for the contrast between the NP-internal reading and the NP-external reading on counting recycled individuals.

In addition to counting recycled individuals, the current analysis can account for more contrasts between the NP-internal reading and the NP-external reading, which are listed below:

- The NP-external reading is only available when a relative measure phrase occupies the object position, but the NP-internal reading is not subject to this constraint;
- When a relative measure phrase has a NP-external reading, the Monotonicity Condition constrains measure functions on event-related domains, whereas when a relative measure phrase has a NP-internal reading, the Monotonicity Condition constrains the individual domain.
- A relative measure phrase with a NP-external reading shows weak island sensitivity. For example, it cannot scope over negation or universal quantifiers. However, a relative measure phrase with a NP-internal reading does not have this property.

The following sections discuss these contrasts and demonstrate how the current analysis captures them.

#### 4. A structural constraint

The first intriguing contrast between the NP-external reading and the NP-internal reading is a structural constraint. Specifically, the NP-external reading may only be observed when a relative measure phrase is used as the object of a transitive verb, but the NP-internal reading is not subject to the same constraint. As shown in (22), a relative measure phrase in the subject position does not give rise to the NP-external reading.

- (22) 30% de kuaguo gongsi gu-le bendiren.  
 30% DE international company hire-ASP locals  
 a. ‘30% of the international companies hired locals.’ (NP-internal)  
 b. #‘30% of the units that hired locals were international companies.’ (NP-external)

According to my analysis, a relative measure phrase with a NP-external reading has the type  $\langle\langle e, \langle e, vt \rangle \rangle, \langle e, vt \rangle\rangle$ . Following Krifka (1989) and Landman (2000), I assume that the agent and the theme are syntactic arguments of a transitive verb, i.e., a transitive verb has the type  $\langle e, \langle e, vt \rangle \rangle$ . Consequently, a relative measure phrase with a NP-external reading must combine with a transitive verb, instead of an element of type  $\langle e, vt \rangle$ , such as an intransitive verb or a verb phrase. Structurally speaking, therefore, the NP-external reading should only be observed when a relative measure phrase is used as the object of a transitive verb.

The same contrast is observed between objects and PP complements, as exemplified by the following examples.

- (23) Zhengfu [PP gei bendiren] fenpei-le 50% de gongwu.  
 government to locals assign-ASP 50% DE public.housing  
 a. ‘The government assigned 50% of the public housing to locals.’ (NP-internal)  
 b. ‘50% of the housing that government assigned to locals is public housing.’  
 (NP-external)

- (24) Zhengfu [PP gei 50% de bendiren] fenpei-le gongwu.  
 government to 50% DE locals assign-ASP public.housing  
 a. ‘The government assigned public housing to 50% of the locals.’ (NP-internal)  
 b. #‘50% of the people that the government assigned public housing to are locals.’  
 (NP-external)

Generally, a preposition is a function taking an individual element of type  $e$  and returning a verb phrase modifier of type  $\langle\langle e, vt \rangle, \langle e, vt \rangle\rangle$ . We may reason that its type is  $\langle e, \langle\langle e, vt \rangle, \langle e, vt \rangle\rangle\rangle$ . Given this type, a relative measure phrase with the NP-external reading cannot combine with a preposition.

It should be noted that the type  $\langle\langle e, \langle e, vt \rangle \rangle, \langle e, vt \rangle\rangle$  is not specific to relative measure phrases. In Mandarin, many event-related modifiers share the same type. For example, it has been a long-standing puzzle that temporal and spatial measure phrases are often used as NP-internal modifiers (Huang 1992), as shown below:

- (25) Libai chi-le yi-ge xiaoshi de pingguo.  
 Libai eat-ASP one-CL hour DE apple  
 ‘Libai ate apples for an hour.’
- (26) Libai kai-le yibai gongli de che.  
 Libai drive-ASP one.hundred km DE car  
 ‘Libai drove for 100 km.’

There is no doubt that *yi-ge xiaoshi* ‘one hour’ and *yibai gongli* ‘100 km’ in these examples measure the temporal duration of the apple-eating event and the distance of the driving event, respectively. Their English counterparts are in the form of *for*-adverbials, but they syntactically look like nominal modifiers.

The current proposal on relative measure items with the NP-external reading can be extended to these event-related NP-internal elements. Specifically, they all involve event-related measurement and have a uniform semantic type— $\langle et, \langle \langle e, \langle e, vt \rangle \rangle, \langle e, vt \rangle \rangle$ . It means that all the NP-internal elements take as arguments an individual predicate and an event-individual relation. The latter enables them to exhibit event-related interpretations. Based on previous studies on temporal and space measure phrases (Moltmann 1991; Krifka 1998; Zwarts 2005; Champollion 2010; a.o.), I suggest the following lexical entries for *yi-ge xiaoshi* ‘one hour’ and *yibai gongli* ‘100 km.’

$$(27) \quad \llbracket \text{one hour} \rrbracket = \lambda P_{et} \lambda R_{\langle e, \langle e, vt \rangle \rangle} \lambda y \lambda e \exists x. P(x) \wedge R(e, y, x) \wedge \mathbf{hour}'(e) = 1$$

$$(28) \quad \llbracket 100 \text{ km} \rrbracket = \lambda P_{et} \lambda R_{\langle e, \langle e, vt \rangle \rangle} \lambda y \lambda e \exists x. P(x) \wedge R(e, y, x) \wedge \mathbf{km}'(e) = 100$$

Similar to relative measure items with an external reading, both *one hour* and *100 km* introduce an event-related measure function, i.e.,  $\mathbf{hour}'$  and  $\mathbf{km}'$ . The former is standardized for events by requiring that  $\mathbf{hour}'(e) = \mathbf{hour}(\tau(e))$ , in which the trace function  $\tau$  maps an event to its running time. The latter must apply to motion events denoted by movement predicates like *walk* and *drive*. The measure function  $\mathbf{km}'$  is standardized for movement events by defining that  $\mathbf{km}'(e) = \mathbf{km}(\sigma(e))$ , in which the trace function  $\sigma$  maps a motion event to the path that the event is linked to.

After combining these NP-internal modifiers with the NP complement, the object phrases in (25) and (26) have the same type as the relative measure phrases with the NP-external reading, i.e.,  $\langle \langle e, \langle e, vt \rangle \rangle, \langle e, vt \rangle \rangle$ . It is predicted that these object phrases cannot be dislocated as topics. This is borne out, as in (29). In these examples, IP should have the type  $\langle e, vt \rangle$ , and hence cannot combine with the topic phrases.

- (29) a. \*Yi-ge xiaoshi de pingguo, [<sub>IP</sub> Libai chi-le].  
           one-CL hour DE apple Libai eat-ASP  
           ‘Libai ate apples for a hour.’  
       b. \*Yibai gongli de che, [<sub>IP</sub> Libai kai-le].  
           one.hundred km DE car Libai drive-ASP  
           ‘Libai drove for 100 km.’

In addition, these event-related lexical items are not the only ones that can claim the type  $\langle \langle e, \langle e, vt \rangle \rangle, \langle e, vt \rangle \rangle$ . Working in an event-free semantics, Szabolcsi (1989, 1992, 2014) essentially suggests that reflexives and bound pronouns also have the same type (minus the event argument). In Keenan’s (2016) theory, quantifiers can be regarded as arity-reducers. They apply to an  $n$ -place function and return an  $(n - 1)$ -place function, and they do so in all their grammatical occurrences. On this view, a relative measure phrase of type  $\langle \langle e, \langle e, vt \rangle \rangle, \langle e, vt \rangle \rangle$  is considered a quantifier that applies to a three-place function of type  $\langle e, \langle e, vt \rangle \rangle$  and returns a two-place function of type  $\langle e, vt \rangle$ .

## 5. Event maximalization suffixes

Mandarin has some verbal suffixes serving to assert that the events denoted by a verb are realized to the maximal degree. Examples of these suffixes include *wan* and *guang*, which are understood as ‘completely,’ ‘entirely’ or ‘fully’ in English. Consider the following sentences with such a suffix:

(30) Libai chi-wan/guang-le ershi-ke shuijiao.  
 Libai eat-WAN/GUANG-ASP twenty-CL dumpling  
 ‘Libai completely ate twenty dumplings.’

(31) Libai chi-wan/guang-le shuijiao.  
 Libai eat-WAN/GUANG-ASP dumpling  
 ‘Libai completely ate the dumplings.’

The uses of *wan/guang* in (31) and (30) are to assert that Libai’s eating of dumplings is realized to the maximal degree (see also Filip 2008). (30) says that twenty dumplings were eaten and none of them was left. In (31), the bare noun *shuijiao* ‘dumplings’ must be understood as a definite noun and refer to the unique and maximal set of dumplings in a given context. The sentence is true if and only if Libai ate all of the dumplings in some time interval. In this paper, I call these suffixes ‘event maximalization suffixes’ (EMS).

Interestingly, the occurrence of an EMS blocks the NP-external reading of a relative measure phrase. Consider (32), in which only the NP-internal reading is available. As a minimal pair to this sentence, (33) shows that the NP-external reading returns when the EMS is removed.

(32) Libai chi-wan/guang-le yi-duo-ban de shuijiao.  
 Libai eat-WAN/GUANG-ASP one-more-half DE dumplings  
 a. NP-internal: ‘Libai completely ate more than half of the dumplings.’  
 b. #NP-external: ‘More than half of the food that Libai completely ate were dumplings.’

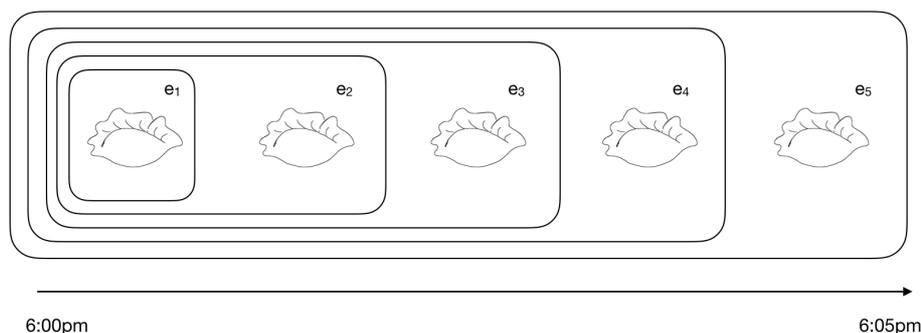
(33) Libai chi-le yi-duo-ban de shuijiao.  
 Libai eat-ASP one-more-half DE dumplings  
 a. NP-internal: ‘Libai ate more than half of the dumplings.’  
 b. NP-external: ‘More than half of the food that Libai ate were dumplings.’

This contrast would be mysterious if the NP-external reading and the NP-internal reading both involved measurement of individuals. However, if the NP-external reading involves measurement in an event-related domain, its disappearance in (32) is expected. The unavailability of the NP-external reading is due to the requirement of EMSs that event predicates they combine with must be telic.

To my knowledge, there have not been formal studies on this kind of verbal suffixes in Mandarin. Both Moltmann (1997) and Piñón (2005) propose formal analyses for English adverbial *completely*, which can be seen as the semantic counterpart of EMSs. While it is not impossible to formalize EMSs using ingredients from these approaches to fit in the current picture, doing

so adds substantial complexity to the compositional semantics developed so far and would take us too far afield. In this section, I just illustrate the function of EMSs with the help of the picture in (34).

(34) The events of eating dumplings



This picture demonstrates a set of partially ordered events, i.e., the events of eating dumplings. This set is ordered relative to the cardinality of the dumplings being consumed in the context (see Krifka 1989, 1998, Kennedy 2012). All the five events are in the set denoted by the verb phrase *chi shuijiao* ‘eat dumplings,’ but only  $e_5$ , in which all the dumplings were eaten, is in the set denoted by the verb phrase *chi-wan shuijiao* ‘completely eat the dumplings.’ In short, the verb phrase with an EMS denotes an event in which its theme participant must be the sum of all the things affected by the event in some time interval.

Consequently, the domain denoted by the verb phrase with an EMS has a trivial part-whole structure. As illustrated in the figure, only  $e_5$  is in the domain of *chi-wan shuijiao* ‘completely eat the dumplings.’ None of its proper subparts belongs to the same domain. In slightly more formal terms, this means that a verb phrase with an EMS is quantized, and hence, according to Krifka (1989, 1998), telic. (35) shows that such a verb phrase is incompatible with an NP-internal temporal measure phrase, which is the counterpart of English *for*-adverbials (see Section 4). By contrast, a verb phrase with an EMS is compatible with (and in fact required by) an *in*-adverbial, as shown in (36) (see also Xuan 2010).

(35) Libai chi-(\*wan/guang)-le yi-ge xiaoshi de shuijiao.  
 Libai eat-WAN/GUANG-ASP one-CL hour DE dumpling  
 ‘Libai (\*completely) ate (\*the) dumplings for one hour.’

(36) Libai yi ge xiaoshi zhilei jiu chi-\*(wan/guang)-le shuijiao.  
 Libai one CL hour within just eat-WAN/GUANG-ASP dumpling  
 ‘Libai \*(completely) ate \*(the) dumplings in one hour.’

According to the literature (Dowty 1979; Krifka 1998; Rothstein 2004; a.o.), a telic predicate can be modified by *in*-adverbials but resists *for*-adverbials. The (in)compatibility of a verb phrase with an EMS is hence a telltale sign about the event structure of the VP denotation.

Returning to relative measurement, the NP-external reading of (32) is blocked by the EMS because event-related measurement is not compatible with telic predicates. In this example, the event domain is characterized by the incremental verb with an EMS, i.e., *chi-wan*. As described before, a verb suffixed by an EMS denotes an event whose theme is maximal with respect to a time interval, and hence it and its sub-parts do not belong to the same domain. In other words, the domain characterized by *chi-wan* has a trivial part-whole structure. Applying a measure function on this domain leads to violation of a general constraint, namely, that the domain must have a non-trivial part-whole structure. This constraint has been repeatedly verified in various measurement constructions, such as pseudopartitives (Schwarzschild 2002, 2006; Champollion 2017), comparatives (Wellwood 2015) and Japanese split measure phrase constructions (Nakanishi 2007).

## 6. Scope and weak islands

Doetjes and Honcoop (1997) argue that quantification over event-individual pairs is sensitive to weak islands in the sense of Szabolcsi and Zwarts (1992). Specifically, event-related interpretations are not available if quantification over event-individual pairs scopes over negation or universal quantifiers. The same pattern is also observed for the NP-external reading of relative measurement.

The NP-external reading and the NP-internal reading of relative measurement show a contrast with respect to scope-taking. When a relative measure phrase has a NP-internal reading, it can take wide or narrow scope relative to negation, as illustrated in (37).

- (37) Lianxiang **meiyou** gu 70% de bendiren.  
 Lenovo not hire 70% DE locals
- a. 'It is not the case that Lenovo hired 70% of the locals.' (*not* > 70%<sub>internal</sub>)  
 b. '70% of the locals were such that Lenovo didn't hire them.' (70%<sub>internal</sub> > *not*)

By contrast, if a relative measure phrase has a NP-external reading, it cannot take wide scope over negation, as shown in (38).

- (38) Lianxiang **meiyou** gu 70% de bendiren.  
 Lenovo not hire 70% DE locals
- a. 'It is not the case that 70% of the people hired by Lenovo were locals.'  
 (*not* > 70%<sub>external</sub>)  
 b. #'70% of the people that Lenovo didn't hire were locals.' (70%<sub>external</sub> > *not*)

Similar to negation, universal quantification has to take scope over relative measure phrases in order to preserve the NP-external reading, as exemplified by the following example.

- (39) Mei nian cha shui de shihou, zhengfu dou hui shencha 20% de  
 every year review tax DE time government DOU will audit 20% DE  
 kuaguo gongsi.  
 international company
- a. ‘Every tax year, 20% of the organizations that the government audits are international companies.’  
 (*every* > 20%<sub>external</sub>)
  - b. #‘20% of the units that the government audits every tax year are international companies.’  
 (20%<sub>external</sub> > *every*)
  - c. ‘Every tax year, the government audits 20% of the international companies.’  
 (*every* > 20%<sub>internal</sub>)
  - d. ‘There are 20% of international companies *x* such that the government audits *x* every tax year.’  
 (20%<sub>internal</sub> > *every*)

(39c) and (39d) show that the universal quantifier can take wide scope or narrow scope with respect to the relative measure phrase with the NP-internal reading. However, it cannot take narrow scope when the relative measure phrase has a NP-external reading, as in (39b).

In the literature, there are several formal analyses offered to capture weak island effects. Szabolcsi and Zwarts (1992) propose that weak islands can be understood if we pay attention to the Boolean operations that particular quantificational elements are associated with. For example, universal quantification corresponds to ‘meet,’ existential quantification ‘join’ and negation ‘complementation.’ A sentence is not acceptable if a quantificational element in this sentence needs to perform its corresponding Boolean operation on an algebraic structure for which the operation is not defined. Doetjes and Honcoop (1997) follow this analysis and argue that complementation and meet cannot be performed on the domain of event-individual pairs. They assume that the domain of event-individual pairs constitutes a join semi-lattice (see Section 3.1). This essentially follows from the fact that the domain of events has no bottom element. Consequently, the domain of event-individual pairs does not have a bottom element either. In (38b) and (39b), the negation and the universal quantifier performs complementation and meet on the domain of event-individual pairs. Since there is no bottom element in this domain, complementation and meet are undefined.

Besides the algebraic semantic approach, Honcoop (1998) and Abrusán (2014) propose two other alternative approaches to weak island effects. The former relies on dynamic semantics, while the latter is based on the semantic and pragmatic properties of questions. The current study remains open to these alternative approaches. The crucial point is that the weak island sensitivity of the NP-external reading provides another piece of evidence for my analysis that this reading is event-related.

## 7. A previous approach: Focus mapping

In this section, I compare my analysis with Ahn and Sauerland’s studies on relative measurement (Sauerland 2014; Ahn and Sauerland 2015a, b). Following the Focus Mapping Hypothesis (Herburger 2000; Beaver and Clark 2008; a.o.), they propose that the NP-external reading of

relative measurement is derived by focusing on the NP complement of a relative measure item. For example, in (40), the NP complement is focused.

- (40) Lianxiang gu-le 30% de [bendiren]<sub>F</sub>.  
 Lenovo hire-ASP 30% DE local  
 ‘Lenovo hired 30% [locals]<sub>F</sub>.’ (NP-external)

According to the Focus Mapping Hypothesis, focus determines the structure of a quantificational element: focused materials are mapped onto the scope, while non-focused materials are mapped onto the restriction. Therefore, in (40), the quantificational structure induced by the relative measure item *30%* can simply be represented as follows:

- (41) [30% *x* : **Lenovo-hired**(*x*)] **locals**(*x*)

Although the focus approach is elegant and based on a widely assumed hypothesis, it faces some empirical problems. First, it cannot account for the event-related properties discussed in this paper. Under the focus approach, both the NP-internal reading and the NP-external reading are individual-related. As a result, the contrasts involving counting recycled individuals, the monotonicity constraint and weak island sensitivity cannot be easily captured in this approach.

Second, at least in Mandarin, focus is not required to derive the NP-external reading. Consider the question-answer pair in (42).

- (42) a. Lianxiang qunian gu-le duoshao bendiren?  
 Lenovo last.year hire how.many locals  
 ‘How many locals did Lenovo hire last year?’  
 b. Lianxiang qunian gu-le [30%]<sub>F</sub> de bendiren  
 Lenovo last.year hire-ASP 30% DE locals  
 (i) ‘Last year, Lenovo hired 30% of the locals.’ (NP-internal)  
 (ii) ‘Last year, Lenovo hired 30% locals.’ (NP-external)

In a question-answer pair, the constituent in the answer corresponding to the *wh*-word is the focus (Jackendoff 1972; a.o.). Accordingly, in (42a), *30%* should be the focus since it directly corresponds to the *wh*-word of the preceding question. Its NP complement as a piece of repeated information is not focused. However, (42b) is still ambiguous, i.e., the NP-external reading is available even though the NP complement of a relative measure item does not bear focus.

## 8. Conclusion

This paper takes up relative measurement in Mandarin. It is argued that relative measurement may involve event-related measurement or individual-related measurement. Furthermore, an explicit compositional analysis is offered to derive these two readings. The analysis is shown to account for various contrasts between individual-related relative measurement and event-related relative measurement. My analysis also highlights the similarities in NP-internal elements with an external event-related interpretation.

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