

Event-related relative measurement: Evidence from Mandarin

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Abstract

Relative measurement expressed by proportional number expressions like *40%* or *two thirds* relates one quantity to another. It has two different readings: (a) the ‘partitive’ reading, as in *Huawei hired 40% of the locals*, expresses the ratio of the locals hired by Huawei relative to all locals; (b) the ‘non-partitive’ reading, as in *Huawei hired 40% locals*, communicates the ratio of the locals hired by Huawei relative to all Huawei’s hires. Based on relative measurement in Mandarin, I argue that the partitive reading and the non-partitive reading parallel the object-related reading and the event-related reading of numeral phrases. Compositionally, proportional number expressions are proposed to be degree quantifiers that take scope at different positions in the partitive reading and the non-partitive reading. The proposed analysis not only accounts for the event-related properties of the non-partitive reading, but also its intricate structural asymmetries and scope properties.

Keywords relative measurement · event-related reading · scope of proportional number expressions · covert focus movement

1 Introduction

There are two kinds of measurement in natural language: absolute measurement, expressible by phrases such as *three liters* and *five inches*, and relative measurement, expressible by proportional number expressions, such as *20%* and *two thirds*. Absolute measurement is about a single measure, as shown in (1), where the numeral phrase *300 locals* refers to the number of locals hired by Huawei. By contrast, relative measurement is about the relation between two measures, as shown in (2), where the relative measure phrase *30% of the locals* refers to the ratio of locals hires by Huawei relative to the local population in a given context.

- (1) Huawei hired 300 locals.
- (2) Huawei hired 30% of the locals.

Most studies on measurement focus on absolute measurement, leaving relative measurement a relatively under-explored research topic. However, a series of recent work by Ahn and Sauerland have revealed that relative measurement has interesting properties that warrant further investigation (Sauerland 2014; Ahn & Sauerland 2015a,b, 2017).

One of their observations is that in many languages relative measurement may be expressed by two constructions. For example, besides (2), where the relative measure phrase is a partitive construction, the following sentence is also acceptable in English.

(3) Huawei hired 30% locals.

The relative measure phrase in this sentence not only differs in form from the partitive relative measure phrase, but it also gives rise to a different meaning. Specifically, the relative measure phrase in (3) refers to the locals hired by Huawei relative, not to the local population, but to the total hires at Huawei. The simplest semantic representations to capture the respective readings of (2) and (3) are given as (4-a) and (4-b). The former expressed by the partitive construction is called ‘partitive reading’, while the latter expressed by the non-partitive construction is called ‘non-partitive reading’.

$$\begin{array}{ll}
 (4) \quad a. & \frac{|\{x \mid \text{local}(x) \wedge \text{hire}(x)(h)\}|}{|\{x \mid \text{local}(x)\}|} = 30\% \quad (\text{Partitive}) \\
 & b. \quad \frac{|\{x \mid \text{local}(x) \wedge \text{hire}(x)(h)\}|}{|\{x \mid \text{hire}(x)(h)\}|} = 30\% \quad (\text{Non-partitive})
 \end{array}$$

The representations in (4) follow the standard theory of generalized quantifiers (Barwise & Cooper 1981): relative measurement is formally treated as quantification over objects, expressing the ratio of one set of objects to the other set of objects. The only difference between (4-a) and (4-b) is that they take different sets as the denominators.

In this paper, however, I’ll show that the difference between the partitive reading and the non-partitive reading goes even deeper than this. The main claim to be defended is that the partitive reading is object-related but the non-partitive reading is event-related. This claim is based on relative measurement in Mandarin, which expresses the two readings using the same form in (5) ¹.

(5) Qùnián, Huáwéi gù-le 30% de bēndirén.
 last.year Huawei hire-ASP 30% DE locals
 a. ‘Last year, Huawei hired 30% of the locals.’ (Partitive)
 b. ‘Last year, Huawei hired 30% locals.’ (Non-partitive)

For concreteness, I argue that the non-partitive reading of (5) can be understood as: *30% of all hiring done by Huawei are hiring of a local*.

I propose a compositional analysis that attributes the two readings of relative measurement to the ambiguity of numeral phrases between an object-related reading and an event-related reading. Krifka (1990) observes that the sentence (6) has two readings. One reading is object-related and the other is event-related.

¹One of the reviewers point out that the acceptance of the non-partitive reading may vary among native speakers. Not every native speaker of Mandarin accepts this reading. In order to address this issue, I conducted a structured survey. Although there were some participants who rejected the non-partitive reading, the results largely prove the existence of this reading. The details of the survey are laid out in Appendix A.

- (6) Four thousand ships passed through the lock last night.
- a. Object-related: ‘There were four thousand distinct ships that passed through the lock last night.’
 - b. Event-related: ‘There were four thousand events of passing through the lock by a ship last night.’

I argue that relative measurement also exhibits both the object-related reading and the event-related reading. More specifically, the former is only found in the partitive reading while the latter is only found in the non-partitive reading. An online structured survey is reported in Appendix A in support of the event-related properties of the non-partitive reading.

My analysis involves two types of measuring modifiers—an object-related measuring modifier and an event-related measuring modifier. The former leads to the object-related reading, while the latter the event-related reading. Structurally, the object-related measuring modifier adjoins to the NP complement within a DP, but the event-related one adjoins beyond the DP domain and can access the event variable stemming from the verbal projections.

Proportional number expressions are analyzed as degree (or number) quantifiers. They take scope at different positions in the partitive reading and the non-partitive reading. Briefly, on the partitive reading, a proportional number expression combines with the object-related measuring modifier and scopes at the edge of the relative measure phrase that hosts it; whereas on the non-partitive reading, a proportional number expression combines with the event-related measuring modifier and its scope is parasitic on the covert focus movement of the NP complement in a relative measure phrase. This scope taking analysis is further supported by the fact that the scope pattern of a proportional number expression is the same as other kinds of degree quantifiers, like comparative quantifiers or modified numerals. Moreover, the generation of the non-partitive reading relies on the covert focus movement of the NP complement in a relative measure phrase, which is constrained by syntactic rules such as the Condition on Extraction Domain (CED) proposed in Huang (1982). The syntactic nature of the movement can be used to account for a subject-object asymmetry observed in Ahn & Sauerland (2017).

The paper is organized as follows. Section 2 probes the partitive reading and the non-partitive reading with respect to their distinct interactions with two phenomena pertaining to events, showing that the non-partitive reading, but not the partitive reading, has event-related properties. Section 3 offers a general compositional mechanism for generating the object-related reading and the event-related reading of numeral phrases, as described in Krifka (1990). Two types of measuring modifiers are defined in this section. Based on this, the two readings of relative measurement are derived in Section 4.1. A novel semantics is proposed for proportional number expressions, which take scope at different positions in the partitive reading and the non-partitive reading. Section 5 discusses scope interactions of relative measure phrases and other scope bearing elements in the two readings of relative measurement. Section 6 accounts for structural asymmetries observed in the non-partitive reading. Section 7 compares my analysis with the scope analysis of superlatives, the reverse proportional reading of *many* as well as with Ahn & Sauerland’s (2017) analysis of relative measurement. Section 8 concludes. Appendix A lays out the details of the online survey.

2 Event-related properties of the non-partitive reading

2.1 The non-partitive reading can be event-related

Krifka (1990) observes that a numeral phrase expressing absolute measurement can be a measurement in an event-related domain, despite its pretense of being inside a noun phrase. Take (7) as an example. The sentence is judged ambiguous: it can have an object-related reading, which guarantees that there are at least 4000 distinct ships that passed through the locks; it can also have an event-related reading, on which there may be fewer than 4000 distinct ships, as long as the total number of lock traversals is at least 4000.

- (7) Four thousand ships passed through the lock last night.
- a. Object-related: ‘Last night, there were 4000 ships such that they passed through the lock.’
 - b. Event-related: ‘Last night, there were 4000 events such that each of them involved a ship passing through the lock.’

The crucial difference in these two readings is that if a certain ship passed through the lock twice, hence contributing two passing events, it is counted once in the first reading but twice in the second reading². In other words, the result of counting objects is not equivalent to that of counting events when an object get involved in more than one event.

Different proposals have been offered to account for the ambiguity in (7) (Krifka 1990; Doetjes & Honcoop 1997; Barker 1999, 2010). The core idea in these proposals is that an absolute measurement in the object domain can be ‘transferred’ to a measurement in an event-related domain (cf. Moore 1994; Musan 1995; Shimada 2009; Schein 2017). I’ll give the formal definition of this kind of measurement in Section 3.1.3.

Turning to relative measurement in Mandarin, intriguingly, the non-partitive reading admits the event-related reading, but the partitive doesn’t. To see this, first consider the two sentences in (8). Both sentences have the counting classifier *réncì*, which morphologically contains the event classifier *cì* ‘time’. According to *The Contemporary Chinese Dictionary*, this classifier adds up the numbers of participants in different events regardless of their identities.

- (8) a. Qùnián, Gùgōng Bówùyùan jiēdài yóukè 1000-wàn réncì.
last.year palace museum admit visitor 10.million person.time
‘Last year, there were 10 million events in which a person visited the Palace Museum.’
- b. Qízhōng, jiēdài guówài yóukè 400-wàn réncì.
among.them admit foreign visitor 4.million person.time
‘Among them, there were 4 million events involving foreign visitors.’

Because of the event classifier, the sentences in (8) only have an event-related reading. For example, the first sentence is true if 3 million different visitors between them toured the museum 10 million times. Suppose that both sentences in (8) are true, then the information can be used to calculate an event-related relative measurement as expressed in (9). Note that the intended interpretation

²Doetjes & Honcoop (1997) and Barker (2010) observe that the event-related reading is felicitous only when the object identities are not relevant in the context and typically, when the numbers are big enough for objects not to be so salient individually.

corresponds to the non-partitive reading³.

- (9) Qùnián, Gùgōng Bówùyùàn jiēdài-le 40% de wàigúo rén.
last.year palace museum admit-ASP 40% DE foreign people
'Last year, the Palace Museum admitted 40% foreigners.'

Let's consider another scenario. Since the Palace Museum is located in Beijing, Beijing citizens have more chances to visit it. The following sentence expresses that the Palace Museum has received 10 million visitors who are Beijing citizens in the past five years.

- (10) Guòqù wǔ nián, Gùgōng Bówùyùàn gòng jiēdài Běijīng shímín 1000-wàn
past five year palace museum total receive Beijing citizen 10.million
rén.
person.time
'In the past five years, there were 10 million events in which a Beijing citizen visited the Palace Museum.'

If ten million tickets were actually purchased by three million different Beijing citizens, (10) is true. Under the same circumstance, however, the sentence in (11) cannot be true if the relative measurement involved in this example receives a partitive reading. Note that a total population of Beijing citizens is twenty million.

- (11) Guòqù wǔ nián, Gùgōng Bówùyùàn jiēdài-le 50% de Běijīng shímín.
past five year palace museum admit-ASP 50% DE Beijing citizen
'In the past five years, the Palace Museum has received 50% of the Beijing citizens.'

Therefore, we can conclude that the proportion in the partitive reading of (11) is not calculated based on the event-related reading of (10). What this suggests is that relative measurement isn't event-related in the partitive reading⁴.

In short, the non-partitive reading can be event-related. By contrast, relative measurement involved in the partitive reading concerns the identification of objects across events and is not compatible with the event-related reading. The conclusion is also confirmed by an online survey that is presented in Appendix A.

³I find that the non-partitive reading is perceived easily when the temporal adjunct like *last year* occurs. A reviewer also notices that event-related readings come out more easily in sentences with such a temporal modifier. This may be because we can only measure specific events happened in a certain period of time.

⁴Doetjes & Honcoop (1997) discover that a relative measure phrase with the partitive reading allows an event-related interpretation when another constituent receives focus (cf. Krifka 1990), as shown below.

- (i) 60% of the ships passed through the lock [at night]_F.

Following Partee (1991), the quantificational structure can be affected by focus. In this example, the focused part serves as the scope of 60%, while the non-focused part the restrictor. Therefore, the verb, which denotes a passing event, is forced into the restrictor. According to Doetjes & Honcoop's computation, the sentence can mean: 60% of the events in which a ship passed through the lock happened at night.

The generation of the event-related reading of (i) is independent of the non-partitive reading studied in this paper. Section 4.3 and Section 7.1 show that the non-partitive reading is allowed only if the NP complement of a relative measure phrase gets focused. So, I'll put aside the focus induced event-related interpretation of a partitive reading.

Note that the occurrence of the event-related reading doesn't require objects to participate in more than one event. Consider (12). A vehicle can be produced only once. So, if one million vehicles were produced, there should be one million vehicle producing events. As a consequence, the event-related reading of (12) won't be truth-conditionally separated from its object-related reading.

(12) Last year, our factory produced one million vehicles.

A sentence with relative measurement also allows both readings in contexts where objects can participate in the relevant event only once, as illustrated in (13).

- (13) Qùnián, wǒmén chǎng shēngchǎn-le 40% de kǎchē.
 last.year we factory produce-ASP 40% DE truck
 a. 'Last year, our factory produced 40% of the trucks.'
 b. 'Last year, our factory produced 40% trucks.'

Since the difference in the event-related reading and the object-related reading is neutralized in this context, it's difficult to tell whether the non-partitive reading is event-related or object-related. It could be ambiguous. However, the next subsection will demonstrate that the non-partitive reading not only *can* be event-related, but is *always* event-related.

2.2 Event Maximalization Suffixes bleed the non-partitive reading

In Mandarin, the non-partitive reading is not always allowed. It is unavailable in sentences whose main verb bears a certain type of aspectual suffixes indicating that the event denoted by the verb is realized to the maximal degree. Based on the fact, I'll show that relative measurement with the non-partitive reading is sensitive to the part-whole structure of an event domain.

Examples of these suffixes include *wán* and *guāng*, which are understood as 'completely,' 'entirely' or 'fully' in English. Consider the following sentences with such a suffix:

- (14) a. Lǐbái chī-wán/guāng-le shí-gè jiǎozi.
 Libai eat-WAN/GUANG-ASP ten-CL dumpling
 'Libai completely ate ten dumplings.'
 b. Lǐbái chī-wán/guāng-le jiǎozi.
 Libai eat-WAN/GUANG-ASP dumpling
 'Libai completely ate the dumplings.'

The use of *wán* or *guāng* in (14-b) and (14-a) is to assert that Libai's eating of dumplings is realized to the maximal degree (Xuan 2010). In (14-a), ten dumplings were eaten and none was left. In (14-b), the bare noun *jiǎozi* 'dumplings' must be understood as the maximal set of dumplings in a given context.⁵ These sentences are true if and only if Libai ate all of the (ten) dumplings in some

⁵A reviewer asked about the interpretation of the bare noun in (14-b). If the bare noun refers to the unique and maximal set of dumplings, it behaves like a definite expression. However, the following sentence does not require the presence of a set of dumplings that Libai ate over two days. In other words, the uniqueness is relativized for each eating event.

- (i) Lǐbái zuótiān hé jīntiān dōu chī-wán-le shǔijǎo.
 Libai yesterday and today dou eat-wan/guang-asp dumplings

time interval. Throughout the paper, I call these suffixes ‘Event Maximalization Suffixes’ (EMS).

Interestingly, the occurrence of an EMS blocks the non-partitive reading of a relative measure phrase. Compare the minimal pairs in (15) and (16), where the (a) examples with EMSs only have partitive readings, whereas the counterparts in (b) have no EMSs and are ambiguous.

- (15) a. Lǐbái chī-wán-le yì-dūo-bàn de hūnjiǎo.
Libai eat-wan-ASP one-more-half DE meat.dumplings
(i) ‘Libai completely ate more than half of the meat dumplings.’
(ii) #‘More than half of the dumplings that Libai completely ate was meat ones.’
- b. Lǐbái chī-le yì-dūo-bàn de hūnjiǎo.
Libai eat-ASP one-more-half DE meat.dumplings
(i) ‘Libai ate more than half of the meat dumplings.’
(ii) ‘More than half of the dumplings that Libai ate was meat ones.’
- (16) a. Zuò zhè-zhǒng jiàngzhī yòng-guāng-le sānfēnzhīèr de jiàngyóu.
make this-CL sauce use-GUANG-ASP two.thirds DE soy.sauce
(i) ‘Two thirds of the soy sauce was completely used to make this sauce.’
(ii) #‘Two thirds of the things completely used to make this sauce was soy sauce.’
- b. Zuò zhè-zhǒng jiàngzhī yòng-le sānfēnzhīèr de jiàngyóu.
make this-CL sauce use-ASP two.thirds DE soy.sauce
(i) ‘Two thirds of the soy sauce was completely used to make this sauce.’
(ii) ‘Two thirds of the things completely used to make this sauce was soy sauce.’

The unavailability of these non-partitive readings is not expected according to the standard theory of GQs. For example, the non-partitive readings of (15-a) can be understood in the following way. Libai completely ate his dinner, which consisted of eighteen meat dumplings and four veggie dumplings. Then, the quantity of the meat dumplings that he ate made up more than half of all dumplings. The non-partitive reading can be informally represented as (17), which involves the cardinality of the dumplings that Libai completely ate. Based on this representation, it is not clear why the verbal aspect affects the availability of the non-partitive reading.

$$(17) \quad \frac{|\{x \mid x \text{ is a meat dumpling} \wedge \text{Libai completely ate } x\}|}{|\{x \mid x \text{ is a dumpling} \wedge \text{Libai completely ate } x\}|} > \frac{1}{2}$$

However, if the non-partitive reading is event-related, its absence in (15-b) and (16-b) can be accounted for. For concreteness, it can be explained as a side-effect of a general constraint on event-related measurement: the domain of an event measure function must have a non-trivial part-whole structure.

To my knowledge, there have not been formal studies on this kind of verbal suffixes in Man-

‘Yesterday and today, Libai ate all the dumplings.’

In fact, Mandarin lacks the English type definite expression. The maximal entity that a bare noun refers to must depend on situations or temporal intervals (see also Dayal 2013). In (i), the bare noun introduces two maximal sets of dumplings that are served in different days. This view is along the line of Chierchia’s (1998) widely-assumed analysis, where Mandarin bare nouns denote intensional maximal entities (i.e., $\lambda s. \bigoplus \{x \mid x \text{ are dumplings in } s\}$), a kind term. The situation variable s is evaluated based on a given context.

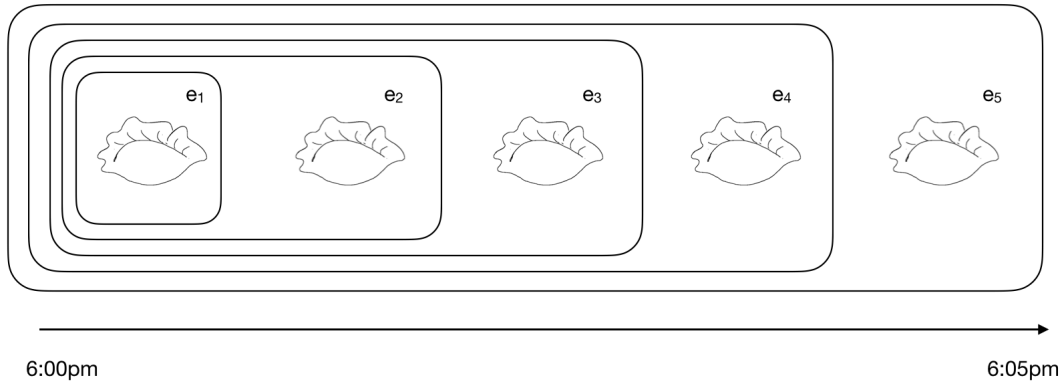


Figure 1: The events of eating dumplings

darin. Both Moltmann (1997) and Piñón (2005) propose formal analyses for the English adverb *completely*, which can be seen as the semantic counterpart of Mandarin EMSs. However, introducing their studies would add substantial complexity to the current discussion and would take us too far afield. I just illustrate the function of EMSs with the help of Figure 1, which 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 *chī shǔijiǎo* ‘eat dumplings,’ but only e_5 , where all the dumplings in the context were eaten, is in the set denoted by the verb phrase *chī-wán shǔijiǎo* ‘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 *chī-wán shǔijiǎo* ‘completely ate the dumplings.’ None of its proper subparts belongs to the same domain. This means that a verb phrase with an EMS is quantized and so telic (Krifka 1989, 1998). (18) shows that such a verb phrase is incompatible with an NP-internal temporal measure phrase, which is the counterpart of English *for*-adverbials (Li 1987; Lin 2008). By contrast, a verb phrase with an EMS is compatible with (and in fact required by) an *in*-adverbial, as shown in (19) (see also Xuan 2010).

- (18) Lǐbái chī-(*wán/*guāng)-le yí-gè xiǎoshí de jiǎozi.
 Libai eat-wan/guang-asp one-cl hour de dumpling
 ‘Libai (*completely) ate (*the) dumplings for one hour.’
- (19) Lǐbái yí gè xiǎoshí zhīnèi jiù chī-*(wán/guāng)-le jiǎozi.
 Libai one cl hour within just eat-wan/guang-asp dumpling
 ‘Libai *(completely) ate *(the) dumplings in one hour.’

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 of the event structure of the VP denotation.

Returning to relative measurement, the non-partitive readings of (15-b) and (16-b) are blocked by the EMS because event-related measurement is not compatible with telic predicates. Take (15-b)

as an example. If its non-partitive reading is event-related, we can informally represent the reading as in (20). μ^{ev} is an event measure function, the semantics of which is discussed in more detail in Section 3.1.3. The notation \oplus represents the algebraic closure for the set following it and forms a join semi-lattice.

$$(20) \quad \frac{\mu^{\text{ev}} \left(\oplus \left\{ e \mid \begin{array}{l} e \text{ is an eating event} \wedge \text{the agent of } e \text{ is Libai} \wedge \\ \text{the theme of } e \text{ is all the meat dumplings he ate} \end{array} \right\} \right)}{\mu^{\text{ev}} \left(\oplus \left\{ e \mid \begin{array}{l} e \text{ is an eating event} \wedge \text{the agent of } e \text{ is Libai} \wedge \\ \text{the theme of } e \text{ is all the dumplings he ate} \end{array} \right\} \right)} > \frac{1}{2}$$

The relative measurement described in (20) measures events, instead of objects. The event domain is characterized by the incremental verb with an EMS, i.e., *chī-wán*. 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 *chī-wán* has a trivial part-whole structure. Applying a measure function to this domain leads to violation of the general constraint on measurement: the domain must have a non-trivial part-whole structure. The 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).

The incompatibility of the non-partitive reading and EMSs indicates that the non-partitive reading **only** involves event-related measurement. Let me explain why. Suppose for the sake of the argument that there are two types of non-partitive readings: one is event-related, the other is object-related. When the event-related non-partitive reading is semantically excluded, we should still be able to access the object-related non-partitive reading. In other words, we should not observe the complete unavailability of the non-partitive reading. Since we do observe the complete unavailability of the non-partitive reading, we can then infer that the event-related non-partitive reading is the only non-partitive reading there of.

In short, the phenomena discussed in Section 2.1 and Section 2.2 lead to the conclusion that the non-partitive reading of relative measurement is always event-related, at least in Mandarin. An adequate analysis should uncover the correlation of the non-partitive reading and the event-related measurement.

3 A compositional analysis of the event-related reading

This section is devoted to the development of a compositional analysis that formally captures the event-related reading of a numeral phrase observed in Krifka (1990). This analysis will provide a basis for the derivation of the non-partitive reading of relative measurement. In a nutshell, I'll propose two measuring modifiers— $\mathbb{M}_\mu^{\text{obj}}$ and $\mathbb{M}_\mu^{\text{ev}}$: the former is responsible for generating the object-related reading, while the latter for generating the event-related reading. Both measuring modifiers bring a contextually given measure function μ , which maps objects to numbers or degrees. Following Krifka (1990), $\mathbb{M}_\mu^{\text{ev}}$ encodes an object-induced event measure function that measures events by measuring the objects participating in the events via μ . Therefore, a numeral phrase containing $\mathbb{M}_\mu^{\text{ev}}$ involves event-related measurement, leading to the event-related reading. Differing from Krifka (1990), my analysis is established on the neo-Davidsonian event semantics and assumes that $\mathbb{M}_\mu^{\text{ev}}$ and $\mathbb{M}_\mu^{\text{obj}}$ occupy different positions: the former adjoins to a position beyond the DP domain, while

the latter is embedded within the DP domain.

3.1 Formal preliminaries

3.1.1 Types

I begin by laying out the basic types: objects (type e), events (type v), degrees or numbers (type d) and truth values (type t). In event semantics, verbal projections denote an event predicate of type $v \rightarrow t$, generalized quantifiers (GQ) of type $(e \rightarrow v \rightarrow t) \rightarrow v \rightarrow t$ that takes scope over verbal projections. For convenience, I define a type synonym Q , as in (21).

$$(21) \quad Q ::= (e \rightarrow v \rightarrow t) \rightarrow v \rightarrow t$$

3.1.2 Neo-Davidsonian event semantics

My proposal is based on an algebraic event semantics as laid out in Krifka (1989, 1998) and elaborated on in Landman (2000) and Champollion (2017). Following neo-Davidsonian event semantics (Parsons 1990; Krifka 1992; Champollion 2017), verbs and verbal projections denote sets of events, type $v \rightarrow t$, as exemplified in (22). The application of a predicative or referential noun phrases to a verbal projection amounts to intersecting two sets of events. This idea goes back at least to Carlson (1984). As an example, the interpretation of *Bob likes Ann* is the intersection of the set of events whose agent is Bob, the set of liking events, and the set of events whose theme is Ann. Arguments are introduced by null thematic role heads, like agent AG and theme TH . As defined in (23), they denote event–object relations. In this paper, the type of a lexical entry is written on the right side of its definition.

$$(22) \quad \llbracket \text{like} \rrbracket^g = \lambda e. * \text{like}(e) \quad v \rightarrow t$$

$$(23) \quad \begin{array}{lll} \text{a.} & \llbracket \text{AG} \rrbracket^g = \lambda x. \lambda e. * \text{ag}(x)(e) & \text{(read as ‘the agent of } e \text{ is } x\text{’)} \quad e \rightarrow v \rightarrow t \\ \text{b.} & \llbracket \text{TH} \rrbracket^g = \lambda x. \lambda e. * \text{th}(x)(e) & \text{(read as ‘the theme of } e \text{ is } x\text{’)} \quad e \rightarrow v \rightarrow t \end{array}$$

The $*$ -operator on the predicates is Link’s (1983) closure under sum (\oplus). It has been widely used to derive plural nominal predicates from singular nominal predicates. Additionally, not only plural nouns but also event predicates and thematic role functions are closed under sum (Krifka 1989; Landman 1996, 2000; Kratzer 2007; Champollion 2017; a.o.). This way, whenever two events are in the denotation of an event predicate, so is their sum. Closure of thematic role functions under sum leads to the fact that thematic role functions are sum homomorphisms. For example, the theme of the sum of two events is the sum of their respective themes.

In this framework, the lexical entry of a verb doesn’t include argument slots. Its arguments are introduced by thematic role heads. As illustrated in Figure 2, the subject and the object first combine with the corresponding thematic role heads, leading to event predicates of type $v \rightarrow t$ (see also Champollion 2015). Then, the resulting event predicates combine with the verb *like* by the rule Predicate Modification⁶. In the end, the sentence denotes an event predicate, which is shifted to the proposition by applying the event existential closure (EC^{ev}).

⁶Unlike the composition shown in Figure 2, AG is often assumed to merge with a verb phrase, instead of a noun phrase. I’m following Champollion (2015) in treating the introduction of agents and themes identically, because the possible difference does not play a role here.

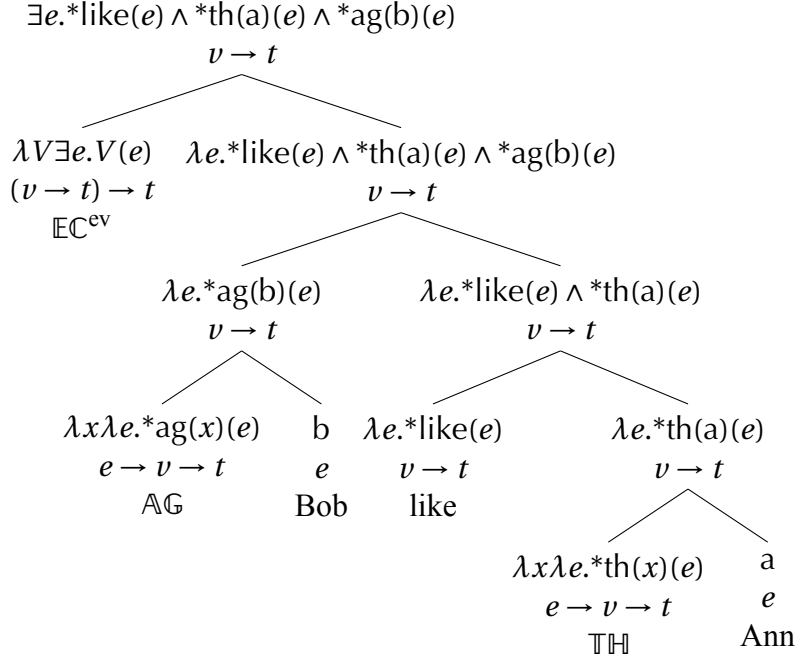


Figure 2: Composition in neo-Davidsonian event semantics (cf. Champollion 2015)

3.1.3 The object induced event measure function

Based on event semantics, Krifka (1990) defines an object induced event measure function to capture event-related measurement (cf. Doetjes & Honcoop 1997; Barker 1999, 2010). The definition is given in (24)⁷.

- (24) Let μ be a measure function, x be an object and R be an event–object relation. Then the object induced event measure function Π can be defined as follows:
 $\Pi(\mu)(R)(x) =$ the event measure function μ^{ev} with the smallest domain such that
- Standardization:** $(\neg \text{iter}(R)(x)(e) \wedge R(x)(e)) \rightarrow (\mu^{ev}(e) = n \leftrightarrow \mu(x) = n)$
 - Generalization:** $(\neg e \circ e' \wedge \mu^{ev}(e) = n \wedge \mu^{ev}(e') = n') \rightarrow (\mu^{ev}(e \oplus e') = n + n')$

This definition contains an important aspectual property—iterativity. Following Krifka (1990) and Doetjes & Honcoop (1997), the aspectual property is defined as in (25).

- (25) **Iterativity (iter)**
 $\text{iter}(R)(x)(e) := \exists e', e'', x'. e' \leq e \wedge e'' \leq e \wedge e' \neq e'' \wedge x' \leq x \wedge R(x')(e') \wedge R(x')(e'')$
 (an 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)

Let me elaborate on this definition with the help of a toy scenario: three students Ann, Bob and Carl visited the Palace Museum last year; Ann and Bob visited the museum once, while Carl twice.

⁷The definition given in (24) is actually closer to Doetjes & Honcoop’s (1997) revision of Krifka’s original definition, where Π does not take the object argument x as argument, but closes the variable in the definition of Standardization.

The scenario involves four visiting events but three visitors, as illustrated by the table on the left hand side:

Vistor	Visiting
Ann	e_1
Bob	e_2
Carl	e_3
Carl	e_4

Vistor	Visiting
Ann	e_1
Bob	e_2
Carl	e_3

Vistor	Visiting
Carl	e_4

We can use Π to measure the visiting events based on the cardinality of the visitors. In particular, Π first standardizes a measure function on objects to another measure function on events by partitioning an event into non-iterative subevents. In this scenario, the event–object pair ‘ $\langle a \oplus b \oplus c, e_1 \oplus e_2 \oplus e_3 \oplus e_4 \rangle$ ’ is in the relation ‘ $\lambda x \lambda e. x$ visited the Palace Museum in e ’. With Standardization, Π can divide the visiting events into two parts $e_1 \oplus e_2 \oplus e_3$ and e_4 , as shown by the table on the right hand side. The former involves visitors $a \oplus b \oplus c$, while the latter the visitor c . Then, the relation ‘ $\lambda x \lambda e. x$ visited the Palace Museum in e ’ is non-iterative with respect to either part. Therefore, the cardinality of the subevents is equal to the cardinality of the visitors involved in them. Therefore, the cardinality of $e_1 \oplus e_2 \oplus e_3$ is 3, while the cardinality of e_4 is 1. Generalization adds up the two values to 4. The result is as if Carl is counted twice.

The event-related reading of a sentence truth-conditionally coincides with its object-related reading when it expresses an event that cannot be iterative. For example, Π correctly predicts that the two readings of (26) don’t differ from each other.

(26) Last year, our factory produced one million vehicles.

In this case, the result of measuring producing events won’t be different from that yielded by measuring produced vehicles directly. The producing event is non-iterative. The same vehicle cannot be produced more than once. As a result, there won’t be a set of vehicles that could be counted more than once. Then, the difference of the event-related reading and the object-related reading isn’t perceived.

In short, Krifka’s (1990) proposal is that the event-related reading is computed by an event measure function that yields the quantity of the objects participating in the relevant event. The event may be non-iterative or partitioned into non-iterative sub-events. After measuring the relevant objects in each cell of the partition, we generalize over all the partial results by claiming additivity for the pertinent measure function on events.

3.2 Two types of measuring modifiers

Based on studies on counting quantifiers or quantity adjectives (Hackl 2009; Szabolcsi 2012; Solt 2015; Wellwood 2015; a.o.), I propose that the structure of a numeral phrase involves a null measuring modifier \mathbb{M} that brings the relevant information for measurement, including the measuring domain, the way of measurement (i.e., measure functions) and the result of measurement (i.e., numbers). In particular, I define two versions of the measuring modifier, the object-related $\mathbb{M}_\mu^{\text{obj}}$, as in (27), and the event-related $\mathbb{M}_\mu^{\text{ev}}$, as in (28).

$$(27) \quad \llbracket \mathbb{M}_\mu^{\text{obj}} \rrbracket^g = \lambda n \lambda P \lambda x. P(x) \wedge g_\mu(x) = n \quad d \rightarrow (e \rightarrow t) \rightarrow (e \rightarrow t)$$

$$(28) \quad \llbracket \mathbb{M}_\mu^{\text{ev}} \rrbracket^g = \lambda n \lambda R \lambda x \lambda e. [\prod(g_\mu)(R)(x)](e) = n \quad d \rightarrow (e \rightarrow v \rightarrow t) \rightarrow (e \rightarrow v \rightarrow t)$$

The interpretations for the two measuring modifiers are relative to any assignment of values to variables. μ is a contextual variable ranging over measure functions of type of $e \rightarrow d$ or $v \rightarrow d$. Specifically, the assignment g assigns a value to the variable μ . It's written as g_μ . Potential values for μ are various measure functions, such as weight, volume, cardinality and distance (see also Wellwood 2015; Ahn & Sauerland 2017).

$\mathbb{M}_\mu^{\text{obj}}$ takes a number and returns a modifier of predicates of type $e \rightarrow t$. The measure function μ applies to an object. It gives rise to a typical object-related measurement. By contrast, $\mathbb{M}_\mu^{\text{ev}}$ takes a number and returns a modifier of event–object relations of type $e \rightarrow v \rightarrow t$. It encodes the object-induced event measure function \prod transferring the object-related measurement associated with μ to the event-related one. Hence, $\mathbb{M}_\mu^{\text{ev}}$ requires an event–object relation R to saturate the argument slot of \prod .

3.2.1 Deriving the object-related reading

Consider the sentence in (29), which is ambiguous between the object-related interpretation and the event-related interpretation.

- (29) Last year, the Palace Museum admitted 4 million foreigners.
- a. Object-related: ‘Last year, there were 4 million foreigners such that the Palace Museum admitted them.’
 - b. Event-related: ‘Last year, there were 4 million events in which the Palace Museum admitted a foreigner.’

The object-related reading is derived based on the structure given in Figure 3. The numeral phrase contains a silent existential determiner $\mathbb{E}\mathbb{X}$, as defined in (30), which maps a property to a GQ. The numeral phrase as a whole denotes a GQ, as in (31), and takes scopes via Quantifier Raising (QR).

$$(30) \quad \llbracket \mathbb{E}\mathbb{X} \rrbracket^g = \lambda P \lambda R \lambda e \exists x. P(x) \wedge R(x)(e) \quad (e \rightarrow t) \rightarrow Q$$

$$(31) \quad \llbracket \mathbb{E}\mathbb{X} \rrbracket^g \left(\llbracket 4 \text{ million} \cdot \mathbb{M}_\mu^{\text{obj}} \rrbracket^g (\llbracket \text{foreigners} \rrbracket^g) \right) \\ = \lambda R \lambda e \exists x. * \text{foreigner}(x) \wedge R(x)(e) \wedge g_\mu(x) = 4,000,000$$

The scope argument is an event–object relation, as in (32). Combining the GQ with its scope argument and applying the event existential closure yields the denotation in (33). In this case, the measure function μ should be understood as a cardinality function.

$$(32) \quad \lambda x \lambda e. * \text{admit}(e) \wedge * \text{ag}(\text{p.m.})(e) \wedge * \text{th}(x)(e)$$

$$(33) \quad \exists x, e. * \text{foreigner}(x) \wedge * \text{admit}(e) \wedge * \text{ag}(\text{p.m.})(e) \wedge * \text{th}(x)(e) \wedge g_\mu(x) = 4,000,000$$

3.2.2 Deriving the event-related reading

Turning to the event-related reading of (29), $\mathbb{M}_\mu^{\text{ev}}$ is applied. Combining $\mathbb{M}_\mu^{\text{ev}}$ with a number results in a modifier of event–object relations. Since the denotation of a DP doesn't have an event variable,

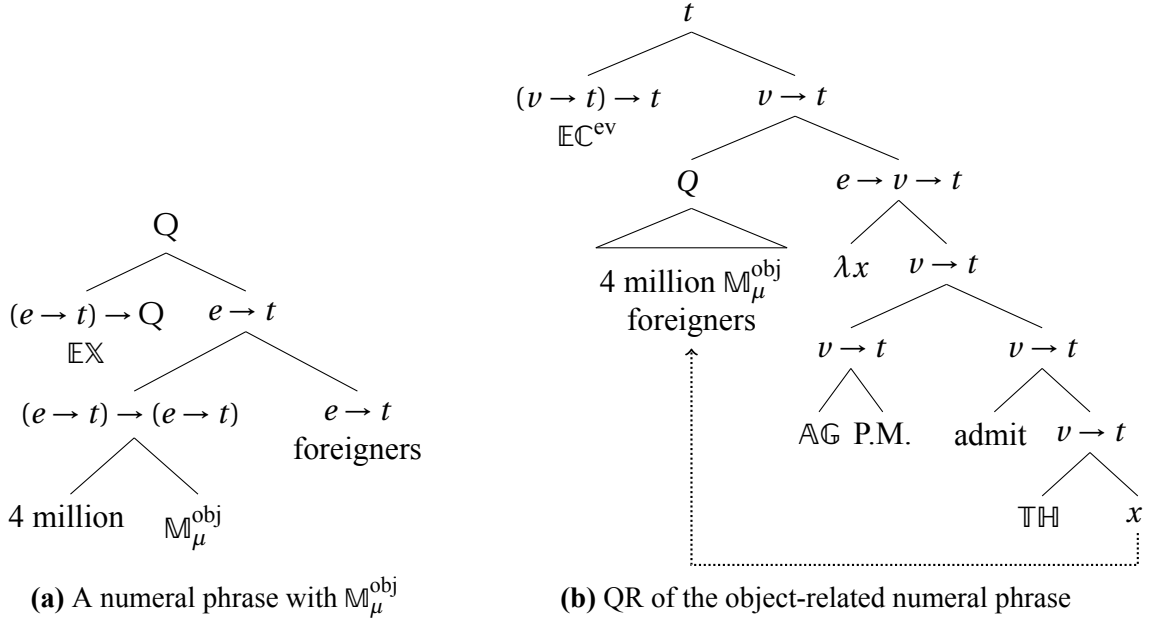


Figure 3: Derivation of the object-related reading

the constituent $[4 \text{ million } \mathbb{M}_\mu^{\text{ev}}]$ should adjoin beyond the DP domain. I assume that it adjoins to a constituent formed with a thematic role head and a bare noun (of type $e \rightarrow t$), as illustrated in Figure 4.

In this paper, the constituent consisting of the theme role head and an NP is called ‘the theme constituent’. When deriving the denotation of the theme constituent in Figure 4, we run into a type mismatch problem: TH and *foreigners* don’t serve as each other’s argument. For this composition to succeed, I borrow the ‘Restrict’ rule, as in (34), proposed by Chung & Ladusaw (2004). This compositional rule allows one to add various properties to the object in an event–object relation.

(34) **Predicate Restriction**

If α is a branching node with daughters β and γ , and $\llbracket \beta \rrbracket^g \subseteq D_{e \rightarrow v \rightarrow t}$ and $\llbracket \gamma \rrbracket^g \subseteq D_{e \rightarrow t}$, then $\llbracket \alpha \rrbracket^g = \lambda x \lambda e. \llbracket \beta \rrbracket^g(x)(e) \wedge \llbracket \gamma \rrbracket^g(x)$

With the use of Predicate Restriction, the combination of TH and the bare noun yields an event–object relation, as in (35), which saturates the second argument slot of $\mathbb{M}_\mu^{\text{ev}}$, generating another event–object relation, as in (36).

$$(35) \quad \llbracket [\text{TH foreigners}] \rrbracket^g = \lambda x \lambda e. * \text{foreigner}(x) \wedge * \text{th}(x)(e)$$

$$(36) \quad \begin{aligned} \llbracket [4 \text{ million-} \mathbb{M}_\mu^{\text{ev}}] \rrbracket^g (\llbracket [\text{TH foreigners}] \rrbracket^g) \\ = \lambda x \lambda e. [\Pi(g_\mu)(\llbracket [\text{TH foreigners}] \rrbracket^g(x))](e) = 4,000,000 \end{aligned}$$

Combining *foreigners* with TH gives it access to events in an innocuous way and the mother node corresponds to ‘themes that are foreigners’.

The resulting event–object relation composes with a silent object existential closure operator EC^{obj} , defined in (37). This existential closure operator is similar to EC^{ev} : EC^{ev} closes the event variable, while EC^{obj} the object variable (cf. Chung & Ladusaw 2004). Note that from its type

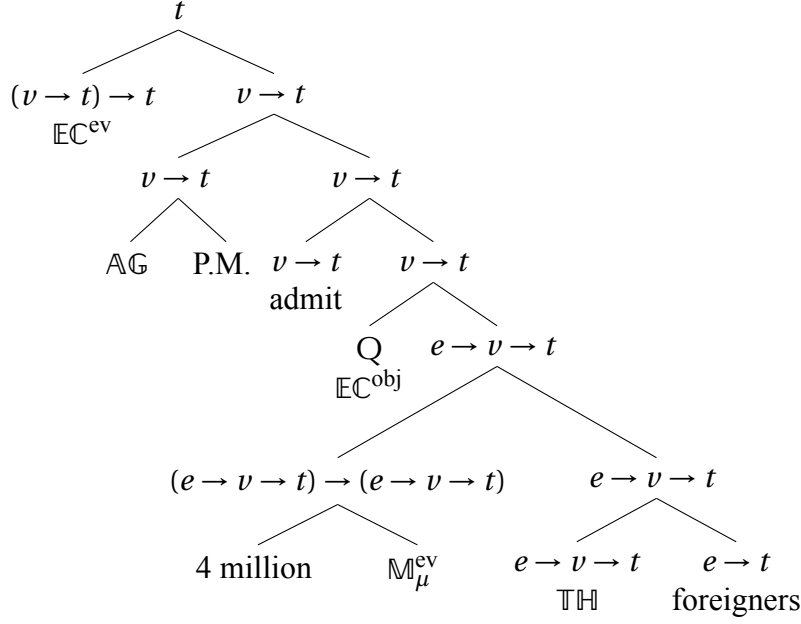


Figure 4: Derivation of the event-related reading

\mathbb{EC}^{obj} is a GQ mapping an event–object relation to an event predicate of type $v \rightarrow t$. Similarly, \mathbb{EC}^{ev} is an event quantifier of type $(v \rightarrow t) \rightarrow t$.

$$(37) \quad \llbracket \mathbb{EC}^{\text{obj}} \rrbracket^g = \lambda R \lambda e \exists x. R(x)(e) \quad \text{Q}$$

Afterwards, the composition proceeds as usual, resulting in the denotation (38), which says: there were 4,000,000 admitting events whose agent is the Palace Museum and whose theme is a foreigner.

$$(38) \quad \exists x, e. * \text{admit}(e) \wedge * \text{ag}(\text{p.m.})(e) \wedge [\Pi(g_\mu)(\llbracket [\text{TH foreigners}] \rrbracket^g)(x)](e) = 4,000,000$$

4 Two readings of relative measurement

So far, I’ve established the semantics of the object-related reading and the event-related reading of numeral phrases. In fact, relative measure phrases are also numeral phrases, as they contains proportional number expressions. So, it’s not surprising that relative measure phrases, too, have both readings. In this section, I propose a novel semantics for proportional number expressions, which are degree quantifiers. When deriving the object-related reading of a relative measure phrase, we use $\mathbb{M}_\mu^{\text{obj}}$ and the proportional number expressions take scope at the edge of the DP domain. As a side effect, the partitive reading is generated. When deriving the event-related reading of a relative measure phrase, we use $\mathbb{M}_\mu^{\text{ev}}$ and the scope of the proportional number expressions is parasitic on the covert focus movement of the relevant theme constituent. The result of the derivation is just the non-partitive reading.

4.1 Proportional number expressions

Relative measure phrases include proportional number expressions. Differing from simple numbers, which are number terms of type d , I assume that proportional number expressions are degree (or number) quantifiers. For concreteness, the denotation of the proportional number expression *40%* is given in (39). It maps a function from numbers to GQs into a GQ. C is a context set of type $e \rightarrow v \rightarrow t$ that restricts the domain of a quantificational item, as assumed for other quantifiers (Westerståhl 1985a,b; de Hoop & Solà 1996; a.o.). The operator **max**, defined in (40-a), is a function mapping a set of numbers to the greatest number (cf. Krifka 1989; Heim 2000). The operator **mxt**, defined as in (40-b), introduces a maximal event of the reference time t_r , whose value is provided by context (Krifka 1989)⁸.

$$(39) \quad \llbracket 40\%_C \rrbracket^g = \lambda D \lambda R \lambda e. \mathbf{mxt}(e) \wedge \frac{\mathbf{max} \{ n \mid \exists e'. e' \leq e \wedge \mathcal{D}(n)(R)(e') \}}{\mathbf{max} \{ n \mid \exists e'. e' \leq e \wedge \mathcal{D}(n)(g_C)(e') \}} = \frac{40}{100} \quad (d \rightarrow Q) \rightarrow Q$$

- (40) a. **max** := $\lambda D \lambda n. n$ is the greatest number in D
 b. **mxt** := $\lambda e. e = \bigoplus (\lambda e' [\tau(e') \leq t_r])$

From the type of the proportional number expression, it's a scope taker⁹. The scope argument is a type $d \rightarrow Q$ element. Structurally, the proportional number expression is merged with a measuring modifier, just like other simple numbers. However, no matter whether $\mathbb{M}_\mu^{\text{obj}}$ or $\mathbb{M}_\mu^{\text{ev}}$ is used, the proportional number expression cannot combine with it directly, due to the type mismatch. Therefore, it has to scope at another position. The following subsections will demonstrate that a proportional number expression takes scope at different positions when being merged with different measuring modifiers. The scope position of a proportional number expression finally determines whether the partitive reading or the non-partitive reading is generated.

4.2 Deriving the partitive reading

With the formal tools that we have defined so far, I proceed to derive the two readings of relative measurement. The partitive reading is taken up in this subsection and the non-partitive reading next. Let me begin by considering the partitive reading of (41-a). Note that the NP complement *wàigúo rén* 'foreigners' is further restricted in the context and refers to foreigners who visited China last year, rather than the whole non-Chinese population.

- (41) Qùnián, Gùgōng Bówùyuan jiědài-le 40% de wàigúo rén.
 last.year palace museum admit-ASP 40% DE foreign people
 a. 'Last year, the Palace Museum admitted 40% of the foreigners.'
 b. 'Last year, the Palace Museum admitted 40% foreigners.'

For the structure of the relative measure phrase, as depicted in Figure 5, the proportional number expression *40%* is merged with $\mathbb{M}_\mu^{\text{obj}}$. We face a type mismatch problem when compositionally deriving the denotation of the whole relative measure phrase: neither *40%* nor $\mathbb{M}_\mu^{\text{obj}}$ can take the other as its argument. This problem can be resolved if *40%* takes scope and leaves a trace of

⁸cf. the mereo-topological notion of *interior* in Grimm (2012).

⁹Scope taking of numbers has been justified on the basis of scope interactions between (modified and unmodified) numerals and modals (Kennedy 2015) as well as on the basis of English *average* (Kennedy & Stanley 2009).

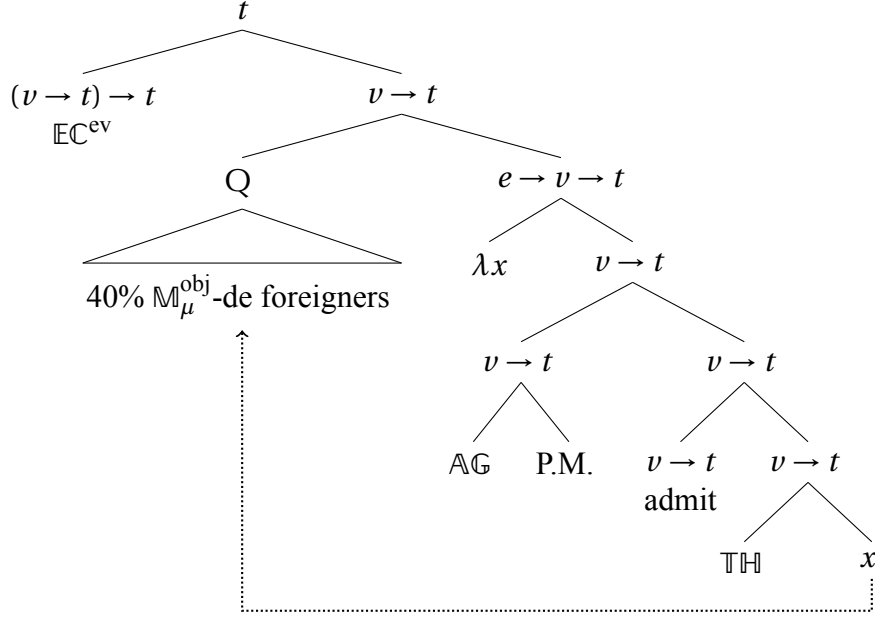


Figure 6: Derivation of the partitive reading

event–object relation denoted by the constituent in its scope yields an event predicate, whose event variable is further closed by \mathbb{EC}^{ev} , resulting in (46)¹⁰.

$$(46) \quad \llbracket \mathbb{EC}^{ev} \rrbracket^g \llbracket 40\% \mathbb{M}_\mu^{obj}\text{-de foreigners} \rrbracket^g \lambda x. (\lambda e. *admit(e) \wedge *ag(p.m.)(e) \wedge *th(x)(e))$$

$$= \exists e. \mathbf{mxt}(e) \wedge \frac{\max \left\{ n \mid \begin{array}{l} \exists x, e'. e' \leq e \wedge *foreigner(x) \wedge *admit(e') \wedge \\ *ag(p.m.)(e') \wedge *th(x)(e') \wedge g_\mu(x) = n \end{array} \right\}}{\max \left\{ n \mid \begin{array}{l} \exists x, e'. e' \leq e \wedge *foreigner(x) \wedge g_C(x)(e') \wedge \\ g_\mu(x) = n \end{array} \right\}} = \frac{40}{100}$$

Suppose that the value of C is a set containing event–object pairs $\langle x, e \rangle$ such that x visited China in e , the formula in (46) says in prose: the maximal number of the foreigners that the Palace Museum admitted divided by the maximal number of the foreigners visiting China equals 40%.

In this derivation, the proportional number expression 40% is merged with \mathbb{M}_μ^{obj} , which encodes object-related measurement. 40% takes scope at the edge of the relative measure phrase, which has the type Q and offers the only appropriate scope position for 40%. Let’s look at Figure 6 again. Beyond the relative measure phrase, no constituent dominating 40% has the type Q . Consequently, QR of 40% can only target the root of the relative measure phrase.

¹⁰ \mathbf{mxt} is used to avoid the problem known as van Benthem’s problem (van Benthem 1989). Specifically, if \mathbf{mxt} were removed, the meaning would be too weak. Suppose that last year 2 million foreigners visited China and the Palace Museum admitted 700 thousand foreigners. We can find a smaller event in which among 1 million foreigners, who visited China, 400 thousand visited the Palace Museum. In this situation, (46) without \mathbf{mxt} would wrongly predict that the sentence is true.

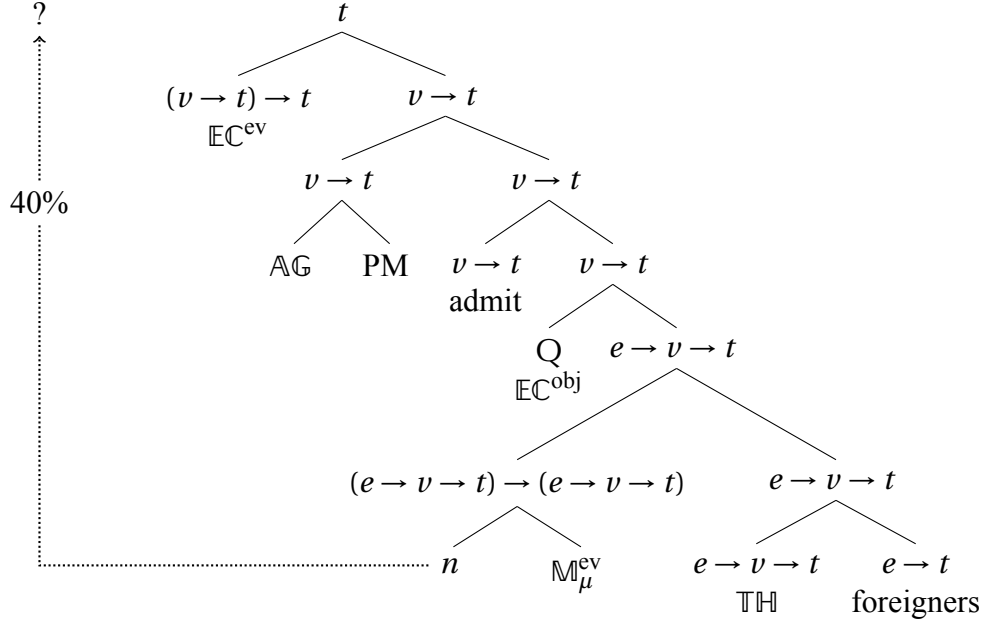


Figure 7: The proportional number expression fails to find an appropriate scope position

4.3 Deriving the non-partitive reading

Turning to the non-partitive reading, I propose that it is generated when a proportional number expression combines with M_μ^{ev} . As discussed in Section 3.2, M_μ^{ev} syntactically appears in a different position from M_μ^{obj} . It can be adjoined to the theme constituent and hence is beyond the DP domain. Consequently, the non-partitive reading is derived based on the syntactic structure in (47).

$$(47) \quad [AG \text{ the Palace Museum}] \text{ admitted } [[40\% M_\mu^{ev}] \text{-de } [TH \text{ foreigners}]]$$

Importantly, the partitive reading and the non-partitive reading are derived based on distinct structures. Although these two readings are expressed by a uniform surface form in Mandarin, they show overt syntactic variation in other languages, like English, German and Korean.

Such a structure is fine from a syntactic perspective. However, we run into a problem when computing the meaning. According to the previous section, the proportional number expression needs to take scope. However, there is no appropriate scope target in (47). Specifically, the type of the proportional number expression, i.e., $(d \rightarrow Q) \rightarrow Q$ dictates that it must QR to a constituent of type Q that dominates it. Unfortunately, the logical form of (47), as in Figure 7, doesn't provide such a scope position.

To handle this problem, we need to assume that the theme constituent also takes scope. Specifically, the event-object relation denoted by the theme constituent is lifted to a scope taker of type $((e \rightarrow v \rightarrow t) \rightarrow v \rightarrow t) \rightarrow v \rightarrow t$, i.e., $Q \rightarrow v \rightarrow t$, as shown in (48). 'Lift' is marked by \uparrow .

$$(48) \quad \begin{aligned} \text{a.} \quad & \llbracket [TH \text{ foreigners}] \rrbracket^g = \lambda x \lambda e. * \text{foreigner}(x) \wedge * \text{th}(x)(e) \\ \text{b.} \quad & \uparrow \llbracket [TH \text{ foreigners}] \rrbracket^g = \lambda f. f(\lambda x \lambda e. * \text{foreigner}(x) \wedge * \text{th}(x)(e)) \end{aligned}$$

It takes scope and adjoins to a constituent of type $v \rightarrow t$. Then, *40%* takes scope between the scope taking event-object relation and the function denoting constituent that normally served as the

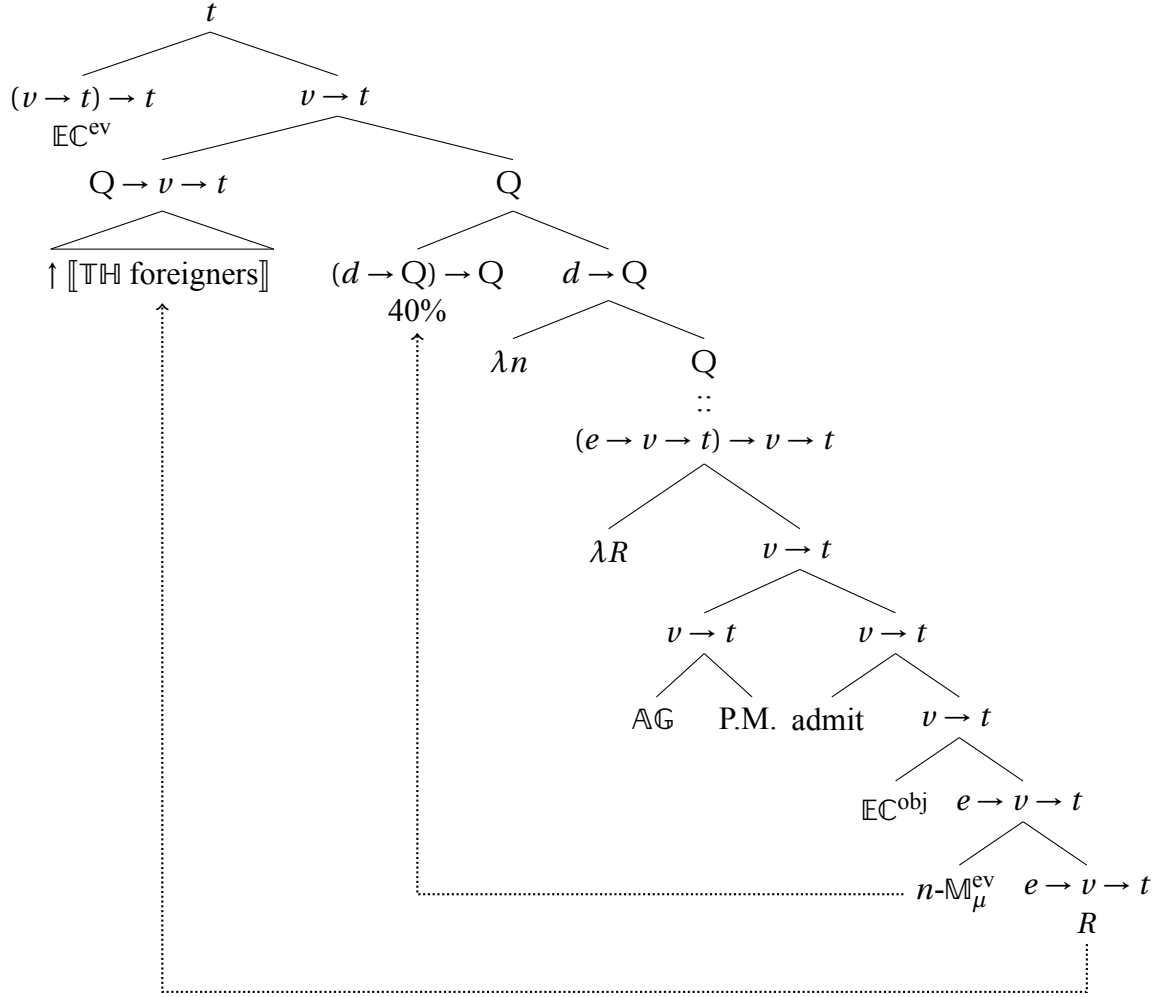


Figure 8: Derivation of the non-partitive reading

scope of the former. The compositional steps are depicted in Figure 8. The resulting configuration is called ‘parasitic scope’ in Barker (2007). QR of the theme constituent derives the constituent whose left-hand daughter is λR . Subsequent QR of *40%* to adjoin to this constituent derives the constituent whose left-hand daughter is λn , which denotes a function mapping numbers to GQs, as given in (49).

$$(49) \quad \lambda n \lambda R \lambda e \exists x. * \text{admit}(e) \wedge * \text{ag}(\text{p.m.})(e) \wedge [\prod(\mu)(R)(x)](e) = n$$

This function is supplied as the first argument to *40%*, resulting in a constituent of type Q , as in (50). Then, combining it with the scope-taking theme constituent and applying $\mathbb{E}\mathbb{C}^{\text{ev}}$ delivers the desirable truth condition, as in (51).

$$(50) \quad \llbracket 40\% \rrbracket^g (\lambda n \lambda R \lambda e \exists x. * \text{admit}(e) \wedge * \text{ag}(\text{p.m.})(e) \wedge [\prod(\mu)(R)(x)](e) = n)$$

$$= \lambda R \lambda e. \mathbf{mxt}(e) \wedge \frac{\max \left\{ n \mid \begin{array}{l} \exists x, e'. e' \leq e \wedge * \text{admit}(e') \wedge * \text{ag}(\text{p.m.})(e') \wedge \\ [\Pi(g_\mu)(R)(x)](e') = n \end{array} \right\}}{\max \left\{ n \mid \begin{array}{l} \exists x, e'. e' \leq e \wedge * \text{admit}(e') \wedge * \text{ag}(\text{p.m.})(e') \wedge \\ [\Pi(g_\mu)(g_C)(x)](e') = n \end{array} \right\}} = \frac{40}{100}$$

$$(51) \quad \llbracket \text{EC}^{\text{ev}} \rrbracket^g \left(\uparrow \llbracket [\text{TH foreigners}] \rrbracket^g (50) \right)$$

$$= \exists e. \mathbf{mxt}(e) \wedge \frac{\max \left\{ n \mid \begin{array}{l} \exists x, e'. e' \leq e \wedge * \text{admit}(e') \wedge * \text{ag}(\text{p.m.})(e') \wedge \\ [\Pi(g_\mu)(\llbracket [\text{TH foreigners}] \rrbracket^g(x))](e') = n \end{array} \right\}}{\max \left\{ n \mid \begin{array}{l} \exists x, e'. e' \leq e \wedge * \text{admit}(e') \wedge * \text{ag}(\text{p.m.})(e') \wedge \\ [\Pi(g_\mu)(g_C)(x)](e') = n \end{array} \right\}} = \frac{40}{100}$$

Given the context in which (41) was uttered, *C* can be understood as a set of event–object pairs $\langle x, e \rangle$ such that *x* is a person visiting the Palace Museum in *e*. In prose, (51) says: there were exactly *n* events in which the Palace Museum admitted a foreign visitor; there were exactly *n'* events in which the Palace Museum admitted a visitor; and *n* divided by *n'* equals 40%.

Correlation of the event-related reading and the non-partitive reading The proposed compositional analysis also predicts that the non-partitive reading is always event-related. Crucially, the composition of the non-partitive reading and that of the partitive reading differ from each other in terms of the measuring modifiers they use. Only when a proportional number expression combines with $\mathbb{M}_\mu^{\text{ev}}$ does it take parasitic scope at a position created by the scope taking of the theme constituent. The parasitic scope mechanism enables the information expressed by the theme constituent to be computed later and only restricts the set occurring in the numerator, leading to the non-partitive reading.

Cover focus movement Let me justify the QR of the event–object relation in the derivation of the non-partitive reading. Ahn & Sauerland (2017) observe that when a relative measure phrase receives a non-partitive reading, its NP complement must be focused in many languages. Indeed, a natural way of inducing the non-partitive reading is to contrast the the NP complement with another NP. An example is given in (52), where *wàigúorén* ‘foreigners’ contrasts with *Zhōnggúorén* ‘Chinese’.

$$(52) \quad \begin{array}{l} \text{Qùnián, Gùgōng Bówùyuan jiědài-le} \quad 40\% \text{ de } wàigúorén, 60\% \text{ de } Zhōnggúorén. \\ \text{last.year palace museum admit-ASP 40\% DE foreigner 60\% DE Chinese} \\ \text{'Last year, the Palace Museum admitted 40\% foreigners and 60\% Chinese.'} \end{array}$$

Unlike Ahn & Sauerland (2017), who assume that the focused NP complement stays in situ and is associated with a sentence-adjoined focus interpretation operator \sim defined in Rooth (1992) (see Section 7.3), I follow the covert focus movement approach, which is suggested by Wagner (2006) and Erlewine & Kotek (2017). Technically, I assume that the \sim operator adjoins to a constituent XP, as in (53), turning XP to a scope taker and introducing a contextually given set \mathfrak{C} that is a subset of the focus value of XP, represented by $\llbracket \cdot \rrbracket_f^g$.

$$(53) \quad \llbracket \sim \mathfrak{C} [XP]_F \rrbracket^g = \lambda f. f(\llbracket XP \rrbracket^g) \text{ defined only if } g_{\mathfrak{C}} \subseteq \llbracket XP \rrbracket_f^g$$

In LF, the lifted focused phrase undergoes covert movement, which corresponds to QR. Note that scope taking doesn't entail the landing site of the covert focus movement. As shown in Figure 8, the theme constituent takes scope at the edge of a constituent of type $\nu \rightarrow t$. In the framework of neo-Davidsonian event semantics, every verb projection has the type $\nu \rightarrow t$. The structure in Figure 8 consists of more than one constituent of type $\nu \rightarrow t$. Semantically, the focused theme constituent can adjoin to any of these constituents and won't give rise to an inappropriate interpretation. Nevertheless, many syntactic analyses have argued that the landing site of focus movement should be in the CP periphery or the VP periphery (Rizzi 1997; Zhang 1997; Belletti 2004). Following these studies, covert focus movement cannot be local and the focused theme constituent should move to the highest constituent of type $\nu \rightarrow t$.

Additionally, following de Hoop & Solà (1996), Cohen (2001) and Ahn & Sauerland (2017), the context set of a proportional number expression is affected by the focus restricted set \mathfrak{C} in its complement. For concreteness, in (54), the context set C taken by *40%* is equal to the union of \mathfrak{C} .

$$(54) \quad [[40\%_C \mathbb{M}_\mu^{\text{ev}}] \text{-de } [\sim \mathfrak{C} [\mathbb{T}\mathbb{H} [\text{foreigners}]_F]]]$$

Given (52), $\llbracket \text{foreigners} \rrbracket_f^g$ denotes a set containing two properties $\llbracket \text{foreigners} \rrbracket$ and $\llbracket \text{Chinese} \rrbracket$. These two properties combine with $\mathbb{T}\mathbb{H}$ in a pointwise style, generating a set of event–object relations as shown below:

$$(55) \quad \left\{ \begin{array}{l} \lambda x \lambda e. * \text{foreigner}(x) \wedge * \text{th}(x)(e) \\ \lambda x \lambda e. \text{Chinese}(x) \wedge * \text{th}(x)(e) \end{array} \right\}$$

The union of \mathfrak{C} delivers a set containing the pairs $\langle x, e \rangle$ such that x is a foreigner or Chinese and x is the theme of e . The resulting set is the context set of *40%*, which is what we want. The reader can check this based on (51).

The covert focus movement of theme constituents can account for the narrow focus reading that arises when the NP in a theme constituent is complex (see also Ahn & Sauerland 2017). Consider (56), which expresses the ratio of college lecturers who visited the Palace Museum to all lecturers, rather than all visitors.

$$(56) \quad \begin{array}{l} \text{Qùnián, Gùgōng Bówùyuan jīdài-le } 40\% \text{ de } [\text{dàxué}]_F \text{ lǎoshī.} \\ \text{last.year palace museum admit-ASP } 40\% \text{ DE college lecturer} \\ \text{'Last year, the Palace Museum admitted } 40\% \text{ [college]}_F \text{ lecturers.'} \end{array}$$

In this example, the relative measure phrase has the structure (57). Computing the focus value of the theme constituent also yields a set of event–object relations, as in (58). *40%* takes as its context set the union of \mathfrak{C} , a subset of the focus value in (58). In other words, the context set of *40%* is a set of $\langle x, e \rangle$ pairs such that x is a lecturer of some school and x is the theme of e . As a result, the domain of the relative measure phrase is restricted to lecturers.

$$(57) \quad [[40\%_C \mathbb{M}_\mu^{\text{ev}}] \text{-de } [\sim \mathfrak{C} [\mathbb{T}\mathbb{H} [\text{college}]_F \text{ lecturers}]]]$$

$$(58) \quad \llbracket [\mathbb{T}\mathbb{H} [\text{college}]_F \text{ lecturers}] \rrbracket_f^g = \left\{ \lambda x \lambda e. P(x) \wedge * \text{lecturer}(x) \wedge * \text{th}(x)(e) \mid P \in \llbracket [\text{college}]_F \rrbracket_f^g \right\}$$

The reader may find that the way that a proportional number expression takes scope in the non-partitive reading looks very similar to the scope taking of superlatives with the relative reading as

proposed in Szabolcsi (1986) and Heim (1999). Indeed, I argue that essentially the same scope taking mechanism is involved in relative measurement and superlatives, although there are still differences between them. A comparison of relative measurement and superlatives is given in Section 7.1.

4.4 States

The present analysis can be extended to sentences with stative verbs. Although Krifka's (1990) analysis of event-related measurement mainly concerns events, a similar shift of measurement domains can also be found with verbs denoting states. Szabó (2007) reports that a state-related reading for (59) can be obtained in a situation in which a port official is writing up an annual report. This sentence is compatible with the case of there having been many fewer than four thousand distinct ships anchored at the port last year.

(59) Four thousand ships were anchored at the port last year.

State-related measurement can be obtained by extending Krifka's object induced event measure function to states. Given the availability of the state-related reading of numeral phrases, we should expect relative measurement to also exhibit the state-related reading, i.e., the non-partitive reading. This expectation is borne out by (60), which is ambiguous between a partitive reading and a non-partitive reading. Note that (60) involves locative inversion. The experiencer of the state of being anchored, *cargo ships*, occupies the object position rather than the subject position. Using locative inversion here is because the non-partitive reading isn't available when relative measure phrases are subjects. I'll return to this issue in Section 6.

- (60) Qùnián, zài Shēnzhèn gǎng tǐngbó-le 30% de huòlún.
 last.year at Shenzhen port anchor 30% de cargo.ship
 a. 'Last year, 30% of the cargo ships were anchored at Shenzhen Port.'
 b. 'Last year, 30% of the ships anchored at Shenzhen Port were cargo ships.'

When (60) receives a non-partitive reading, the identity of objects are not concerned. If a cargo ship was anchored more than once at Shenzhen Port, it can be counted more than once.

4.5 Wrapping up

I have argued, based on the event-related properties discussed in Section 2, that the non-partitive reading and the partitive reading should be understood as having different domains of measurement: the former measures a domain of events while the latter a domain of objects. The current section illustrates the compositional derivations of the two readings. The main components of the proposal are summarized below:

1. For numeral phrases, the object-related reading and the event-related reading are compositionally derived via using different measuring modifiers, i.e., $\mathbb{M}_{\mu}^{\text{obj}}$ and $\mathbb{M}_{\mu}^{\text{ev}}$. The former encodes an ordinary measure function and is responsible for generating the object-related reading. The latter encodes the object induced event measure function defined in Krifka (1990), which delivers the event-related reading. Structurally, $\mathbb{M}_{\mu}^{\text{obj}}$ is embedded in a DP, whereas $\mathbb{M}_{\mu}^{\text{ev}}$ is adjoined to the theme constituent, i.e., beyond the DP domain.

2. Proportional number expressions basically express arithmetical division. In terms of composition, they are degree quantifiers of type $(d \rightarrow Q) \rightarrow Q$. At LF, a proportional number expression QRs to a constituent of type Q and leaving a trace of type d .
3. When a proportional number expression combines with $\mathbb{M}_{\mu}^{\text{obj}}$, it has to take scope at the edge of its DP host. The resulting LF only gives rise to the partitive reading.
4. When a proportional number expression combines with $\mathbb{M}_{\mu}^{\text{ev}}$, the scope of the proportional number expression is parasitic on the covert focus movement of the theme constituent. The resulting LF only generates the non-partitive reading.

Thus, this analysis shows that the distinguishing features of the object-related reading and the event-related reading underlie the ambiguity of relative measurement. These two readings are associated with different measuring modifiers. A proportional number expression merging with different measuring modifiers scopes differently, resulting in the two readings of relative measurement.

The rest of the paper is devoted to elaborating on the consequences of the analysis. In Section 5, I discuss the scope of relative measure phrases. In the present analysis, proportional number expressions take scope at different positions in the partitive reading and the non-partitive reading. As a result, we should expect the two readings to give rise to distinct scope interactions. In Section 6, I demonstrate that positing covert focus movement of the theme constituent can account for intriguing structural asymmetries observed in the literature.

5 Scope interactions between relative measure phrases and other scope bearing elements

According to the present analysis, a relative measure phrase can be decomposed into two components—a proportional number expression and a constituent involving a measuring modifier ($\mathbb{M}_{\mu}^{\text{obj}}$ or $\mathbb{M}_{\mu}^{\text{ev}}$). The proportional number expression of type $(d \rightarrow Q) \rightarrow Q$, which is a degree quantifier, takes scope at different positions in the partitive reading and in the non-partitive reading, leaving a trace of type d . In this sense, relative measurement is similar to constructions involving scope taking of degree quantifiers, such as *how-many* questions (Cresti 1995; Rullmann 1995; Fox & Hackl 2006; a.o.), modified numerals (Takahashi 2006; Kennedy 2015), superlatives and comparatives (Szabolcsi 1986, 2012; Kennedy 1997; Heim 2000; Hackl 2009; a.o.). If the present analysis is on the right track, we should expect relative measure phrases to show the same scope properties as these constructions.

It's well known that degree quantifiers cannot take scope over negation. For example, degree questions are sensitive to negative islands (Szabolcsi & Zwarts 1993; Rullmann 1995; Fox & Hackl 2006; a.o.), as shown in (61), and comparative quantifiers *-er than X* cannot scope over negation (Kennedy 1997; Heim 2000), as shown in (62).

(61) *How much does John not weigh?

(62) Mary isn't taller than 4 feet.

- a. The maximal degree to which Mary is tall is not bigger than 4 feet (*not* > *-er*)
- b. #The maximal degree to which Mary is not tall is bigger than 4 feet. (*-er* > *not*)

Interestingly, a relative measure phrase interacts differently with negation when it receives different readings. When the relative measure phrase is associated with a partitive reading, it can take wide or narrow scope relative to negation. For example, (63) is ambiguous.

- (63) Lǎnxiǎng méiyǒu gù 70% de běndìrén.
 Lenovo not hire 70% de locals
 a. ‘It’s not the case that Lenovo hired 70% of the locals.’ (*not* > 70%_{part})
 b. ‘70% of the locals were such that Lenovo didn’t hire them.’ (70%_{part} > *not*)

If negation scopes over the relative measure phrase, (63) is true if the locals hired by Lenovo made up less than 70% of the local population. On the other hand, if the relative measure phrase takes scope over negation, (63) is true in case there were some locals that Lenovo did not hire and they made up (at least) 70% of the local population.

By contrast, if a relative measure phrase participates in a non-partitive reading, it cannot take scope over negation, as shown in (64), which only have one well-formed reading:

- (64) Lǎnxiǎng méiyǒu gù 70% de běndìrén.
 Lenovo not hire 70% de locals
 a. ‘It’s not the case that 70% of Lenovo’s employees were locals.’ (*not* > 70%_{n-part})
 b. #‘70% of the people that Lenovo didn’t hire were locals.’ (70%_{n-part} > *not*)

(64) is true when the local employees at Lenovo made up less than 70% of all the employees at Lenovo, i.e., the reading indicated in (64-a). If the reading in (64-b) were available, the sentence would be true in a scenario in which Lenovo hired 100 people out of 200 applicants, and among the 100 applicants that were not hired 70 were locals.

In the present analysis, the proportional number expression takes scope at the edge of a relative measure phrase, giving rise to a GQ compositionally, and then the GQ takes scope. The wide scope reading of the relative measure phrase in (63) is derived by the LF in (65). In event semantics, I follow Krifka (1989) and assign the lexical entry in (66) to the negative item *not*. Simply speaking, *not* denotes an event predicate modifier: it takes an event predicate *V* and returns another event predicate characterizing a set of events, each of which takes place within some time and doesn’t include a subevent in *V*¹¹.

- (65) $[70\%_C \lambda n [\text{EX} [n - \mathbb{M}_\mu^{\text{obj}} \text{ locals}]]] \lambda x [\text{not} [[\text{AG Lenovo}] \text{ hire} [\text{TH } x]]]$

- (66) $[\text{not}]^g = \lambda V \lambda e. \text{mxt}(e) \wedge \neg \exists e'. e' \leq e \wedge V(e')$ ($v \rightarrow t \rightarrow (v \rightarrow t)$)

Accordingly, the proportional number expression doesn’t take scope over *not*, whose scope only contains the *e*-type trace left by the scope taking of the relative measure phrase. Nothing rules out the LF in (65). Therefore, when the relative measure phrase is associated with the partitive reading, it can scope over negation.

¹¹The commonly assumed definition for negation is $\lambda p. \neg p$, a proposition operator rather than an event predicate modifier. This definition requires negation to take scope over event existential closure (Landman 1996; Champollion 2015). Consequently, it won’t interact with any GQs in event semantics. However, this analysis misses the scope interaction of negation and *for*-adverbials in English, as discussed in Krifka (1989) and Zucchi & White (2001).

Turning to the example in (64), the wide scope reading of the relative measure phrase is generated by the LF in (67), which has the non-partitive reading. According to the present analysis, the scope of the proportional number expression is parasitic on the scope of the theme constituent.

$$(67) \quad [\text{TH locals}] 70\% \lambda n \lambda R [\text{not} [[\text{AG Lenovo}] \text{hire} [\text{EC}^{\text{obj}} [n\text{-M}_{\mu}^{\text{ev}} R]]]]$$

In this case, the proportional number expression takes scope, leaving a trace of type d in the scope of *not*. This is the same as what we observed in (61) and (62). Like these constructions, a general constraint prevents the proportional number expression from scoping out of negation. In particular, the semantic representation computed based on (67) is (68).

$$(68) \quad \exists e. \text{mxt}(e) \wedge \frac{\max \left\{ n \mid \begin{array}{l} \exists e'. e' \leq e \wedge \neg \exists x, e''. e'' \leq e' \wedge * \text{hire}(e'') \wedge * \text{ag}(l)(e'') \wedge \\ [\Pi(g_{\mu})([\text{TH locals}]^g)(x)](e'') = n \end{array} \right\}}{\max \left\{ n \mid \begin{array}{l} \exists e'. e' \leq e \wedge \neg \exists x, e''. e'' \leq e' \wedge * \text{hire}(e'') \wedge * \text{ag}(l)(e'') \wedge \\ [\Pi(g_{\mu})(g_C)(x)](e'') = n \end{array} \right\}} = \frac{40}{100}$$

Given the definition of **max** in (40-a), the numerator in the formula (68) refers to the maximal number from the set of numbers that are not yielded by measuring the events in which Lenovo hired locals. However, this set is infinite and hence has no maximal number. So if the LF in (67) can be generated, it is a presupposition failure (Rullmann 1995). The same problem is also shown for the denominator.

In addition to negation, Kennedy (1997) and Heim (2000) notice that a quantificational DP also interferes with the scope taking of a degree quantifier. For example, (69) is judged unambiguous. The sentence is true if every girl has the same height and each of them is 1 ft taller than John. That is, the universal quantifier scopes over the comparative quantifier *-er than John*.

(69) Every girl is 1 ft taller than John.

However, the reading in which *-er than John* scopes over the universal quantifier is not attested. In other words, the sentence cannot be used to describe a situation in which the shortest girl is 1 ft taller than John but the other girls are more than 1 ft taller than John.

A relative measure phrase demonstrates the same scope pattern when it is associated with a non-partitive reading. Consider (70) and (71). Both are unambiguous and the proportional number expression *one third* takes narrow scope relative to the quantificational DP in each sentence.

- (70) Měigè xúeshēng dōu dú-le sānfēnzhīyī de xiǎoshū.
 every student DOU read-ASP one.third DE novel
 a. 'For each student x , x read one third novels.' (*every* > *one.third*_{n-part})
 b. # 'The novels that every student read made up one third of the books that every student read.' (*one.third*_{n-part} > *every*)
- (71) Zhènghǎo yǒu liǎng-gè xúeshēng dú-le sānfēnzhīyī de xiǎoshū.
 exactly have two-CL student read-ASP one.third DE novel
 a. 'There are exactly two students each of which read one third novels.' (*exactly two* > *one.third*_{n-part})

- b. #‘The novels that exactly two students read made up one third of the books that exactly two students read.’ *(one.third_{n-part} > exactly two)*

The available readings (70-a) and (71-a) are true just in case the students under discussion each read an amount of novels that made up one third of the books that they read. (70) and (71) indeed are true in the relevant contexts. By contrast, the readings in (70-b) and (71-b) are unavailable. For example, (70-b) says: every student read n books and n' novels; n' divided by n equals one third. It doesn't mean that every student read one third novels. In other words, if not every student read one third novels, the sentence (70) should be true, contrary to fact.

Although the actual cause of the quantificational DP intervention effect is not very clear (see the comments given in Heim (2000)), the fact that it shows up both in the comparative construction and in the non-partitive reading of relative measurement suggests that these constructions involve the same scope taking mechanism.

Interestingly, when the partitive reading is concerned, it also prefers to take narrow scope relative to a quantificational DP in the sentence. For example, (72) has an acceptable reading that each student read a different set of novels that made up one third of all novels. The other reading, which is less acceptable, is that there were a specific set of novels that made up one third of all novels such that each student read them.

- (72) Měigè xúeshēng dōu dú-le sānfēnzhīyī de xiǎoshū.
 every student DOU read-ASP one.third DE novel
 a. ‘For each student x , x read one third of the novels.’ *(every > one.third_{part})*
 b. ??‘There were one third of the novels that every student read.’ *(one.third_{part} > every)*

Nevertheless, the wide scope reading is not always blocked. In (73), the relative measure phrase modified by a relative clause can take scope over the universal quantifier.

- (73) Měigè xúeshēng dōu dú-le zhè-gè shūjià shàng de sānfēnzhīyī de xiǎoshū.
 every student DOU read-ASP this-CL shelf on DE one.third DE novel
 a. ‘For each student x , x read one third of the novels on this shelf.’ *(every > one.third_{part})*
 b. ‘There were one third of the novels on this shelf that every student read.’
(one.third_{part} > every)

The possibility of the wide scope reading in (73-b) is expected since the modified relative measure phrase has a partitive reading and denotes an ordinary GQ. However, the unavailability of (72-b) is left unexplained. The scope of a relative measure phrase with the partitive reading calls for a more sophisticated analysis. Since this is not the core of the present study, I leave it for future study.

Finally, relative measure phrases don't always take narrow scope when they have the non-partitive reading. As has been noted in the literature, degree quantifiers can interact with intensional verbs. For example, the sentence in (74) is ambiguous. Its two interpretations can be formally translated as (74-a) and (74-b). The former says that the paper is less than 10 pages in every permitted world. So, it's not allowed to be longer. The latter says that the shortest paper among all the permitted worlds is less than 10 pages. So, the paper can be longer than 10 pages.

- (74) The paper is required to be less than 10 pages.
 a. $\forall w \in \mathbf{Acc}_{w_0}. \mathbf{max} \{n \mid (\text{length}_w p) = n\} < 10 \text{ pages}$ *(require > less-than)*

- b. $\max \{n \mid \forall w \in \mathbf{Acc}_{w_0}.(\text{length}_w p) = n\} < 10 \text{ pages}$ (*less-than > require*)

Similarly, a relative measure phrase with the non-partitive reading can take wide scope relative to intensional verbs. Consider (75), which is ambiguous. For the reading in (75-a), the sentence is judged true if Libai hasn't decided on how many people the company would hire, but wanted to have 40% of all the hired people to be locals. In this case, Libai must know the information about the proportion. In addition, the sentence can be judged true if Libai has decided on how many locals and non-locals the company would hire, but he hasn't calculated the proportion. In this case, the information about the proportion shouldn't be in his doxastic worlds. In other words, the proportional number expression must scope out of *xiang* 'want'.

- (75) Lǐbái xiǎng gù 40% de běndirén.
Libai want hire 40% DE locals
- a. 'For each of Libai's desire worlds, he hires 40% locals.' (*want > 40%_{n-part}*)
b. 'Libai wants to hire n locals and n' non-locals; n divided by $n + n'$ equals 40%.' (*40%_{n-part} > want*)

6 Structural asymmetries

According to the analysis of the non-partitive reading, the scope target of a proportional number expression is created by the scope taking of a constituent of type $e \rightarrow v \rightarrow t$, which corresponds to the covert focus movement of the theme constituent. As a syntactic operation, covert focus movement is sensitive to syntactic constraints. This section will show that the CED, proposed in Huang (1982), only allows the theme constituent to undergo covert focus movement. This can account for structural asymmetries observed for the availability of the non-partitive reading.

Ahn & Sauerland (2017) point out that the non-partitive reading of relative measurement exhibits an intriguing subject-object asymmetry in some languages, such as Mandarin and English. As shown in (76), the non-partitive reading does not appear when a relative measure phrase occurs in the subject position.

- (76) 30% de kuàguó gōngsī gù-le běndirén.
30% de international company hire-asp locals
- a. '30% of the international companies hired locals.'
b. #'30% of the hirers that hired locals were international companies.'

In addition, the generalization about the subject-object asymmetry is further verified by the fact that the non-partitive reading is unavailable when relative measure phrases are derived subjects. In particular, the relative measure phrase is the subject of the passive in (77) and the non-partitive reading is not perceived.

- (77) 40% de běndirén bèi Huáwéi gù-le.
40% DE locals BEI Huawei hire-ASP
- a. '40% of the locals were hired by Huawei.'
b. #'40% of people hired by Huawei were locals.'

Regarding unaccusative verbs, the non-partitive reading is allowed when a relative measure phrase

stays in the post-verbal (or object) position, as in (78-a), but becomes absent when the relative measure phrase moves to the pre-verbal (subject) position, as in (78-b).

- (78) a. Dǎo-le yíbàn de xiàngshù.
 fall-ASP half DE oak
 (i) ‘One third of the oaks fell.’
 (ii) ‘Half of the falling trees were oaks.’
 b. Yíbàn de xiàngshù dǎo-le.
 half DE oak fall-ASP
 (i) ‘One third of the oaks fell.’
 (ii) #‘Half of the falling trees were oaks.’

One of the reviewers suggests that the subject–object asymmetry may result from the fact that subjects are less easy to be focused. According to Ahn & Sauerland’s and my own analyses, the non-partitive reading is available only when the NP complement of a relative measure phrase gets focused. If it’s difficult to assign focus to subjects, the absence of the non-partitive reading in (76) is expected. However, it’s not clear to me how difficult it is for a subject to bear focus. In Mandarin, subjects can be contrastive focus or associate with a focus-sensitive adverb, as exemplified in (79).

- (79) a. [Huáwéi]_F gù-le hěnduō běndìrén, dàn [Liǎnxiǎng]_F méiyǒu.
 Huawei hire-ASP many locals but Lenovo didn’t
 ‘[Huawei]_F hired many locals, but [Lenovo]_F didn’t.’
 b. Zhǐyǒu [běndìrén]_F néng shēnqǐng gōngwū.
 only locals can apply.for public.housing
 ‘Only [local people]_F can apply for public housing.’

In fact, the structural asymmetry is not restricted to subjects and objects. The same contrast is observed for objects and PP adjuncts, i.e., the non-partitive reading is allowed when a relative measure phrase occurs as an object, but not when a relative measure phrase occurs as a PP adjunct, as exemplified by the following examples.

- (80) Zhèngfǔ [PP gěi běndìrén] fēnpèi-le 40% de gōngwū.
 government to locals assign-asp 40% de public.housing
 a. ‘The government assigned 40% of the public housing to locals.’
 b. ‘40% of the housing that the government assigned to locals were public housing.’
 (81) Zhèngfǔ [PP gěi 40% de běndìrén] fēnpèi-le gōngwū.
 government to 40% de locals assign-asp public.housing
 a. ‘The government assigned public housing to 40% of the locals’
 b. #‘40% of the people that the government assigned public housing to were locals’

The structural asymmetry appears to be a syntactic constraint of some sort, because the prohibited non-partitive reading in Mandarin and English is available in languages like German and Korean and there is no obvious reason why it should be semantically deviant. According to the present analysis of the non-partitive reading of relative measurement, the scope of a proportional number expression is parasitic on the covert focus movement of the theme constituent. In other words, the non-partitive reading is licensed by the covert focus movement of the theme constituent. Erlewine & Kotek (2017) shows that covert focus movement is sensitive to syntactic islands. Hence, it’s not surprising to assume that the covert focus movement in relative measurement is also constrained by similar syntactic conditions.

In the Government and Binding (GB) theory, many structural asymmetries of movement have been discovered. Huang (1982) reduces subject islands and adjunct islands to the CED, which essentially prevents an element from being extracted from a syntactic constituent that is not a complement. Therefore, in English, *wh*-phrases cannot move out of a constituent that is a subject or an adjunct, as illustrated in (82).

- (82) a. Who₁ do you like pictures of *t*₁?
 b. *Who₁ do [pictures of *t*₁] please you?
 c. ??Which paper₁ did John go to sleep [without reading *t*₁]?

If the covert focus movement is restricted by CED, the absence of the non-partitive reading in (76) and (81) is expected. In these two structures, *international company* and *locals* are embedded in the subject and the adjunct, respectively. Evacuating them leads to the violation of CED.

The CED is considered a theoretical generalization and should be universal. If CED indeed provides an explanation for the structural asymmetry, why does German not show a similar structural asymmetry? For example, the relative measure phrase in (83) occurs in the subject position, but the non-partitive reading is still possible.

- (83) 30 Prozent STUDierende arbeiten hier.
 30 Percent-NOM studierende-NOM work here
 ‘30 percent of workers here are students.’ (Ahn & Sauerland 2017: 5)

In Ahn & Sauerland’s analysis, the non-partitive reading of a relative measure phrase is built on the so-called ‘split topicalization’ construction in German. According to Ott (2012, 2015), split topicalization is insensitive to constraints that apply to regular instances of movement. For example, in (84), the complement of *kein* ‘no’ can move out of the subject.

- (84) [Briefe an Gary]₁ haben mich [keine *t*₁] erschreckt.
 letters to Gary have me no frightened
 ‘As for letters to Gary, none of them have frightened me.’ (Ott 2015: 159)

The focused NP complement in (83) may undergo a covert extraction that is the same as split topicalization (cf. Ahn & Sauerland 2017, see Section 7.3). I suspect that German only seems to not exhibit a subject-object asymmetry because of the availability of such a covert extraction¹².

¹²Anna Szabolcsi (p.c.) points out that in Hungarian, although the non-partitive reading is allowed when a relative measure phrase is used as the subject, there is still a constraint. For example, (i), which has the non-partitive reading, is acceptable. This sentence doesn’t express a singing action, but a prototypical activity associated with membership in a group. Therefore, the subject is not a typical agent. By contrast, if the relative measure phrase is used as an agent, as in (ii), the sentence is marked for the non-partitive reading.

- (i) 30% nő énekel a kórusban. (ii) ??Tegnap 30% nő énekelte a Messiást.
 30% woman sings the choir-in yesterday 30% woman sang the Messiah-acc
 ‘30% of the choir members are women.’ ‘Yesterday 30% of the people performing Messiah were women.’

Maybe in other languages like German and Korean, using relative measure phrase as subjects in the non-partitive reading also bears some constraints. It’s worth exploring this issue in future study.

7 Comparisons

7.1 Scope of superlatives

The present analysis of relative measurement is reminiscent of the split scope analysis of superlatives. Specifically, superlatives are ambiguous among an absolute reading and two relative readings, as shown in (85).

- (85) John put the tallest plant on the table.
- a. Absolute: John put the plant that was taller than any other plant on the table.
 - b. Relative: John put a taller plant on the table than anyone else did.
 - c. Relative: John put a taller plant on the table than the plants he put anywhere else.

Focus has a disambiguating effect on the relative readings (Szabolcsi 1986; Heim 1999). The placement of focus on *John*, as in (86-a), facilitates the relative reading in (85-b) and precludes the relative reading in (85-c). By contrast, when the focus is on *Mary*, as in (86-b), it disambiguates in favor of the reading in (85-c).

- (86) a. [John]_F put the tallest plant on the table.
 b. John put the tallest plant on the [table]_F.

Szabolcsi (1986) and Heim (1999) propose that the different readings of a superlative sentence are derived by allowing the superlative morpheme *-est*, a degree quantifier with the semantics in (87), to take scope in different positions in a clause. The definition follows Hackl's (2009) implementation based on Heim's (1999) semantics.

- (87) $[-est_C]^g = \lambda D \lambda x. \forall y \in C. y \neq x \rightarrow \mathbf{max}\{n \mid D(d)(x)\} > \mathbf{max}\{n \mid D(d)(y)\}$
 $(d \rightarrow e \rightarrow t) \rightarrow (e \rightarrow t)$

According to the type, *-est* has to take scope at the edge of a constituent of type $e \rightarrow t$. The NP embedded in the superlative phrase has the type $e \rightarrow t$ and hence provides such a scope target. As shown in (88-a), the absolute reading is derived when *-est* scopes DP-internally. The first argument *D* is a function from degrees to properties. Therefore, the comparison is about the height of plants.

- (88) a. John put [DP the [-est_C] $\lambda n. [\text{NP } n\text{-tall plant}]$] on the table.
 b. [John]_F [-est_C] $\lambda n \lambda x. [\text{IP } x \text{ put the } n\text{-tall plant on the table}]$.
 c. [the [table]_F] [-est_C] $\lambda n \lambda x. [\text{IP } \text{John put the } n\text{-tall plant on } x]$.

The covert focus movement of *John* creates a constituent of type $e \rightarrow t$, which can serve as the scope target for *-est*. When *-est* raises and adjoins to the constituent, as in (88-b), the first argument is saturated by the function mapping degrees to people who put plants on the table. The comparison is about the height of the plants on the table. As a result, the relative reading (85-b) is derived. The same scope taking process is applied to *the table*, as in (88-c), which contains a focused NP *table*. As a result, the relative reading (85-c) is generated.

Similar to the present analysis of proportional number expressions, the clausal scope of *-est* is parasitic on the covert focus movement of a focused phrase. In this sense, we may classify proportional number expressions and the superlative morpheme as the same class of degree quantifiers.

However, they exhibit an important difference. Although distinct foci give rise to distinct relative readings in a sentence with a superlative morpheme, the same is not true for proportional number expressions. Consider the sentence in (89). Although the NP complement of the preposition *gěi* ‘to’ bears focus, the non-partitive reading remains the same.

- (89) Zhèngfǔ [PP gěi [běndirén]_F] fēnpèi-le 40% de gōngwū.
 government to locals assign-asp 40% de public.housing
 a. ‘The government assigned locals 40% of the public housing.’ (Partitive)
 b. ‘The government assigned locals 40% public housing.’ (Non-partitive)
 c. #‘40% of the public housing assigned by the government were assigned to locals.’ (Non-partitive)

This example raises two problems for the present analysis. First, if the theme argument *gōngwū* ‘public housing’ is not focused, the whole theme constituent should not undergo covert focus movement and the non-partitive reading (89-b) will be wrongly prevented. However, this problem can be avoided if the theme argument is a second occurrence focus (SOF, see Partee 1991). This point is clearly illustrated by the following dialogue:

- (90) A: Zhèngfǔ [PP gěi sùoyǒu rén] fēnpèi-le 40% de gōngwū, 60% de
 government to all people assign-asp 40% de public.housing 60% DE
 liánzūwū.
 low-rent.housing
 ‘The government assigned locals 40% public housing and 60% low-rent housing.’
 B: Búdùi, zhèngfǔ zhǐ [PP gěi [běndirén]_F] fēnpèi-le 40% de gōngwū,
 no government only to local assign-asp 40% de public.housing
 60% de liánzūwū.
 60% DE low-rent.housing
 ‘No. The government only assigned locals 40% public housing and 60% low-rent housing.’

A’s utterance has a non-partitive reading. *Public housing* and *low-rent housing* contrast with each other. They are first occurrence foci in this utterance. Turning to B’s utterance, the focus is apparently assigned to *locals*, but the contrast between *public housing* and *low-rent housing* still holds. They are treated as SOF in this utterance. As a result, they can also undergo covert focus movement.

Second, why must the scope of the proportional number expression in (89) be parasitic on the covert focus movement of the theme argument *public housing*? Even though *public housing* can be treated as SOF, *locals* bears the main focus and is able to create a scope target for 40%. In my opinion, the scope taking of 40% is exclusively parasitic on *public housing* because the context set of the former is locally determined by the focus value of the latter. As discussed in Section 4.3, the structure of the relative measure phrase in (89) is analyzed as follows:

- (91) [[40%_C M_μ^{ev}]-de [~ ℄ [TH [p.h.]_F]]]

The context set *C* is the union of ℄, a subset of the focus value of the theme constituent [TH [p.h.]_F]. Consequently, the quantificational domain of 40% is restricted to the set of event–object pairs $\langle x, e \rangle$ such that *x* is a kind of housing and serves as the theme of *e*. If the scope of 40% were parasitic on

the covert focus movement of *locals*, the LF would be (92).

$$(92) \quad [\text{to } [\text{locals}]_F] \quad 40\%_C \quad \lambda n \lambda R [\text{the government } R \text{ assigned } [n \cdot \mathbb{M}_\mu^{\text{ev}} [\mathbb{T}\mathbb{H} \text{ p.h.}]]]$$

Suppose that the preposition *to* is a goal functional head denoting $\lambda x \lambda e. *gl(x)(e)$, the truth condition computed based on (92) would be:

$$(93) \quad \exists e. \text{mxt}(e) \wedge \frac{\max \left\{ n \mid \begin{array}{l} \exists x, y, e'. e' \leq e \wedge *assign(e') \wedge *ag(g)(e') \wedge *gl(y)(e') \wedge \\ *local(y) \wedge [\Pi(g_\mu)([\mathbb{T}\mathbb{H} \text{ p.h.}]]^g(x)](e') = n \end{array} \right\}}{\max \left\{ n \mid \begin{array}{l} \exists x, y, e'. e' \leq e \wedge *assign(e') \wedge *ag(g)(e') \wedge g_C(y)(e') \wedge \\ [\Pi(g_\mu)([\mathbb{T}\mathbb{H} \text{ p.h.}]]^g(x)](e') = n \end{array} \right\}} = \frac{40}{100}$$

This is not a well-formed representation. In the denominator, y and e' bear the relation g_C . That is, y is a kind of housing and y is the theme of e' . As a result, the assigning event has two themes, i.e., x and y . Many Neo-Davidsonian frameworks (Carlson 1984; Parsons 1990; Landman 2000) assume the Unique Role Requirement, which entails that an event can only have a unique theme. The denominator in (93) violates this requirement.

7.2 The reverse proportional reading of *many*

The non-partitive reading of relative measurement is also comparable to the reverse proportional reading of the determiners *many*. Westerståhl (1985a) first notes that besides the regular proportional reading, *many* has an additional ‘reverse’ proportional reading that can be paraphrased by reversing the role of the VP and the NP. In particular, (94) is ambiguous between the reading (a) ‘many of the Scandinavians have won the Nobel Prize in literature’ and (b) ‘many of the winners of the Nobel Prize in literature were Scandinavians’. Furthermore, Herburger (1997) argues that the reverse proportional reading of (94) is only possible when the NP complement of *many* is focused.

$$(94) \quad \text{Many } [\text{Scandinavians}]_F \text{ have won the Nobel Prize in literature.}$$

At first glance, the reverse proportional reading looks very similar to the non-partitive reading, which can also be paraphrased as the reverse version of the partitive reading and requires the NP complement to be focused. However, I see them as independent phenomena. One reason for this is that the reverse proportional reading of *many* doesn’t show the structural asymmetries observed for the non-partitive reading. In Mandarin, for example, the subject *many* phrase can give rise to the reverse proportional reading, as shown in (95).

$$(95) \quad \begin{array}{llll} 90 \text{ niǎndài yǐlái, hěnduō } [\text{zhōngguóorén}]_F & \text{dé-guò} & \text{àoshù guànjūn.} \\ 90 \text{ years} & \text{since many} & \text{Chinese} & \text{get-ASP IMC champion} \\ \text{‘Since 1990s, many [Chinese]}_F & \text{have won the IMC championship.} \end{array}$$

In addition, departing from the non-partitive reading, the reverse proportional reading is not blocked by EMSs, as exemplified by (96). This fact indicates that the reverse proportional reading is not always event-related and the quantification induced by *many* in this reading may involve the domain of objects.

- (96) Lǐbái chī-wán-le hěnduō [xiājiǎo]_F.
 Libai eat-WAN-ASP many shrimp.dumpling
 ‘Many of the dumplings that Libai ate up were shrimp ones.’

Theoretically, not all the studies agree that the reverse proportional reading is semantically represented as the reverse version of the quantificational structure given by the regular proportional reading. Recently, Romero (2015) has argued that the meaning of (94) should be paraphrased as (97), which actually expresses a comparison of two proportions (cf. Cohen 2001).

- (97) The proportion of Scandinavians that have won the Nobel Prize in literature is large compared to a threshold based on the proportions of inhabitants of other worlds regions that have won the Nobel Prize in literature.

Even though the focus on the NP complement of *many* still plays an important role in Romero’s analysis, the resulting interpretation doesn’t look similar to the non-partitive reading.

7.3 Focus mapping

Ahn & Sauerland (2017) provide another analysis for the two readings of relative measurement. Focus also plays the crucial role in their analysis. Mainly based on the data from German and Korean, they argue that the non-partitive reading appears when the NP complement of a relative measure phrase is focused, as exemplified by the following German sentence.

- (98) 30 Prozent [studierende]_F arbeiten hier.
 30 Percent-NOM studierende-NOM work here
 ‘30 percent of workers here are students.’ (Ahn & Sauerland 2017: 5)

They propose that the relative measure phrase is an unstable constituent in the sense of Ott (2012, 2015). Simply put, the unstable constituent is generated by merging 30% and *běndirén*, but neither of them is clearly syntactically dominant in this merger. Consequently, two NPs in this unstable constituent must split by covert movement of 30% at LF. Therefore, the LF of (98) is:

- (99) [30 percent [ι \mathfrak{C}]] [$\sim \mathfrak{C}$ [ι [λx [the_x [students]_F works here]]]]

The LF involves the following assumptions:

1. Following Fox (2002) and Sauerland (1998, 2004), Ahn and Sauerland assume that the covert movement of 30% leaves a copy of the moved material that is interpreted as the definite description *the_x* co-indexed with the λ -operator;
2. The silent ι operator maps a set of objects to the single object that is the supremum of the set, i. e. the smallest object z such that all objects x in the set form part of z .

$$\llbracket \iota \rrbracket^g = \lambda P. \mathbf{sup} \{x \mid P(x)\}$$

3. The silent \sim operator is the focus interpretation operator defined in Rooth (1992). It takes a contextually given variable \mathfrak{C} and is attached to a constituent α containing focus. This operator requires \mathfrak{C} to be a subset of the focus value of α .

In (99), the focus value of *students*, i.e., $\llbracket \text{students} \rrbracket_f^g$, is a set of alternative properties. The focus value of a bigger constituent is computed with use of tools in Roothian focus semantics (Rooth 1992). As a result, the complement of \sim has the focus value as follows¹³:

$$(100) \quad \llbracket \iota (\lambda x [\text{the}_x [\text{student}]_F \text{ works here}]) \rrbracket_f^g = \left\{ \mathbf{sup} \{x \mid P(x) \wedge \text{work.here}(x)\} \mid P \in \llbracket \text{students} \rrbracket_f^g \right\}$$

\mathfrak{C} is a subset of the focus value. Assuming that the only alternative to *students* is *teachers*, \mathfrak{C} has only two elements, i.e., all the teachers who work here and all the students who work here. In (99), *percent* combines with a constituent consisting of ι and \mathfrak{C} . The application of ι to \mathfrak{C} returns a maximal object consisting of the workers who may be a student or a teacher.

Ahn and Sauerland assign the lexical entry in (101) to *percent*. Specifically, *percent* takes as argument an object, a number and a property, and returns a proposition. It also involves a contextually given measure function μ . (102) shows how the truth condition of the full sentence in (99) is derived. The final result can be paraphrased as ‘30% of the people working here are students.’

$$(101) \quad \llbracket \text{percent} \rrbracket^{g:\mu} = \lambda x \lambda n \lambda P. \frac{\mu(x \oplus (\mathbf{sup}(P)))}{\mu(x)} = n\%$$

$$(102) \quad \frac{\mu((\iota \mathfrak{C}) \oplus (\iota \lambda x. * \text{student}(x) \wedge \text{work.here}(x)))}{\mu(\iota \mathfrak{C})} = 30\%$$

Ahn and Sauerland acknowledge a connection to the well-known Focus Mapping Hypothesis, which assumes that focus determines the structure of a quantificational element: focused materials are mapped onto the scope, while non-focused materials are mapped onto the restriction (see Partee 1991; Herburger 1997, 2000; Beaver & Clark 2008; a.o.). In (98), the quantificational structure induced by the relative measure item, in this case 30%, has the representation as follows:

$$(103) \quad [30\%] \underbrace{[\text{works here}]}_{\text{restriction}} \underbrace{[\text{students}]}_{\text{scope}} := [30\% x : \text{work.here } x] (* \text{student } x)$$

This quantificational structure can also be read as ‘30% of the people hired by Lenovo were locals,’ which is equivalent to the truth condition given in (102).

Obviously, this analysis doesn’t explain the correlation of the event-related reading and the non-partitive reading, since events don’t play a role here. In addition, this analysis doesn’t provide a direct semantic account for the scope pattern of relative measure phrases with the non-partitive reading. This is because the movement of a proportional number expression leaves a trace of type e , instead of a degree trace. As a result, it’s not clear why the scope pattern of a relative measure phrase with the non-partitive reading is the same as degree quantifiers, as we have observed in Section 5. Moreover, the structural asymmetries don’t receive an explicit analysis in this analysis.

8 Conclusion

Based on neo-Davidsonian event semantics, this paper has offered a compositional analysis for the partitive reading and the non-partitive reading of relative measurement, which are reduced to the

¹³Strictly speaking, the computation of the focus value in (100) is problematic. That’s because λ -abstraction is applied to a set of alternatives evoked by focus. As pointed out by Shan (2004), such a λ -abstraction is compositionally defective.

object-related reading and the event-related reading of numeral phrases, respectively.

The main innovation lies in the distinction between an object-related measuring modifier $\mathbb{M}_\mu^{\text{obj}}$ and an event-related measuring modifier $\mathbb{M}_\mu^{\text{ev}}$. They adjoin to different places, governed by distinct type requirements. $\mathbb{M}_\mu^{\text{obj}}$ adjoins to an NP, while $\mathbb{M}_\mu^{\text{ev}}$ adjoins to the theme constituent, i.e., beyond the DP domain. $\mathbb{M}_\mu^{\text{obj}}$ is responsible for generating the object-related reading, while $\mathbb{M}_\mu^{\text{ev}}$ is responsible for generating the event-related reading.

Proportional number expressions receive a novel semantics: they are degree (or number) quantifiers. When combined with $\mathbb{M}_\mu^{\text{obj}}$, a proportional number expression takes scope at the edge of a relative measure phrase, giving rise to the partitive reading. When combined with $\mathbb{M}_\mu^{\text{ev}}$, the scope of a proportional number expression is parasitic on the covert focus movement of the theme constituent. The result is the non-partitive reading.

A Appendix: An online survey of event-related measurement

An online survey was conducted to collect native Mandarin speakers' judgments on counting recycled objects, i.e., the objects participating in more than one event, in the two readings of relative measurement. As discussed in Section 2.1, if the non-partitive reading is event-related, we should expect participants to count a recycled object multiple times; likewise, if the partitive reading is object-related, we should expect participants to count a recycled object only once. This relationship is summarized as follows:

Reading	Hypothesis	Counting a recycled object
non-partitive	event-related	multiple times
partitive	object-related	once

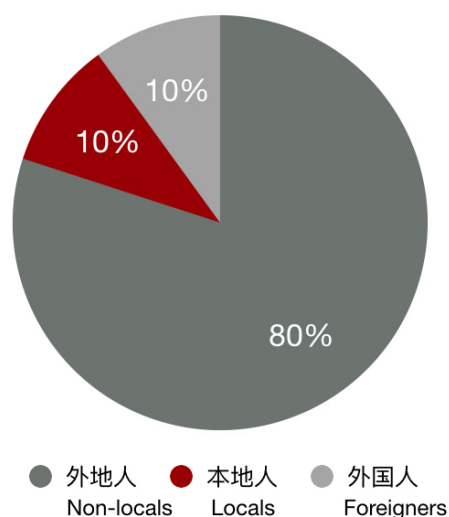
The survey had two tasks. Task I was designed with two goals. First, it served to confirmed the availability of the non-partitive reading. The non-partitive reading has been taken up by a few studies, but as one of the reviewers noted, it is not universally accepted by Mandarin speakers. So Task I provided an opportunity to verify the presence of this reading. Second, given the potential inter-speaker variability, Task I served to single out two groups of speakers: those that accepted the non-partitive reading and those that did not. Task II tested how recycled objects were counted among the two groups of speakers, seeking to find any potential relationship between the acceptability of the non-partitive reading and the way of counting recycled objects. The design and results of the two tasks are described in more detail below.

A.1 Task I

Materials There were eight test items in Task I: four targets and four controls. Each target item presented participants with a 'proportion' diagram. The participants were asked to evaluate, based on the diagram, the acceptability of sentences with relative measure phrases. A sample target task is given in Figure 9. In this task, the diagram represented the people that Lenovo hired last year. A participant needed to judge whether the test sentence was acceptable based on the diagram. A 7-point Likert scale was used for the task. The minimum point on the scale was '0' (completely unacceptable), and the maximum was '6' (completely acceptable). A participant was free to choose any

The people hired by Lenovo last year

联想去年的雇人情况



Is the following sentence acceptable based on the diagram?

Qùnián, Liǎnxiǎng gù-le 10% de běndirén.
last.year Lenovo hire-asp 10% de locals

0	1	2	3	4	5	6
Completely unacceptable			Marginally acceptable			Completely acceptable

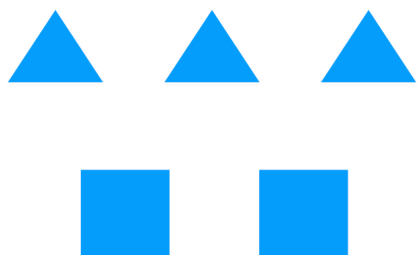
Figure 9: A sample target item in the first part

point between 0 and 6 down to a decimal place. The intermediate point 3 was labeled ‘marginally acceptable’.

If a participant could interpret the sentence as the non-partitive reading, i.e., ‘Lenovo hired 10% locals’, s/he would assign a higher score to the sentence. Since the total number of the locals was not given, the partitive reading, i.e., ‘Lenovo hired 10% of the locals’, was uninterpretable. If a participant only interpreted the test sentence as the partitive reading, she would assign a low score to the item.

The four control items involved RMPs and were uncontroversially unacceptable given the diagrams, as shown in Figure 10. The responses to the control items were used to compare with the responses to the target items and also served to check whether participants paid enough attention during the experiment. All the items were pseudo-randomized, and were presented in Simplified Chinese characters, on the online survey platform Qualtrics.

Participants A total of 63 persons participated in this study. They were mostly college students



Is the following sentence acceptable based on the diagram?

Shàngtú zhishǎo yǒu sān-gè zhèngfāngxíng.
last.picture at.least have three-cl square

0	1	2	3	4	5	6
Completely unacceptable			Marginally acceptable			Completely acceptable

Figure 10: A sample control item in the first part

studying in various universities in Mainland China, recruited with the generous help of their course instructors. A small number of the participants might be personal friends of these instructors and hence might not be college students. Since the survey was anonymous, these participants could not be told apart. All of the participants volunteered to participate in the survey and received no compensation.

Results A total of 63 online surveys were collected. There was a participant who failed more than one control items, so their data were excluded. We divided the rest of the 62 participants into three groups based on their performance in Task I. Group I and Group II consistently assigned scores to the target items. Consistency is defined as assigning a similar rating to three or four target items, out of the four target items. As summarized in the following table, Group I contained 35 participants who offered high ratings (≥ 3.5) to three or four target items; whereas, Group II contained 10 participants who assigned low ratings (≤ 2) to three or four target items. The participants who did not consistently assign a rating were put into a third group. There were 17 participants.

Group	No. of people	Rating of target items
Group I	35	≥ 3.5 for three or four items
Group II	10	≤ 2 for three or four items
Group III	17	not rating the items consistently

Task I successfully verified the presence of the non-partitive reading. In fact, Group I is the biggest group out of the three groups, suggesting that a large proportion of the population have access to the non-partitive reading. In addition, the presence of Group II also corroborated the reviewer's observation that not all speakers had access to the non-partitive reading.

A.2 Task II

Materials The second task involved presenting participants with a scenario established by a short descriptive passage, which consists of three sentences. The participants were asked to evaluate, based on the scenario, the acceptance of two sentences with quantity information.

Each scenario depicted an event allowing recycled objects—*passengers being served, ships passing through ports, interviewers being interviewed and actors performing in shows*. For each event, we designed two scenarios involving recycled objects, one supporting the partitive reading, called 'IS', as shown in Figure 11, and the other supporting the non-partitive reading, called 'ES', as shown in Figure 12. In each scenario, a target item as well as a control item is included. As a result, we have 4×2 scenarios and 8×2 test items.

The scenario in Figure 11 supported the partitive reading. For concreteness, the first sentence provided the total number of the cargo ships owned by Beihai City. The second sentence gave the number of the Beihai cargo ships that passed through Shenzhen port. The third sentence indicated that there were 10 recycled objects, i.e., 10 cargo ships passed through the port twice. No information was given about the number of all the ships that passed through Shenzhen port. As a consequence, the percentage in the target item, the first test sentence below the scenario, can only be the proportion of the cargo ships passing through Shenzhen port out of all the cargo ships owned by Beihai City. In other words, the sentence should receive a partitive reading.

According to the scenario, 20 out of 100 cargo ships of Beihai City passed through Shenzhen Port. This did not match the content conveyed by the target item, which said that 30% of Beihai's cargo ships passed through the port. The target item should not be acceptable in the scenario. However, if the recycled objects could be counted twice, the proportion in the target item would be correct, i.e., $10 + (2 \times 10)/100 = 30\%$. Like the first task, a participant was asked to judge the acceptability of sentences by assigning a score between '0' and '6' (a 7-point Likert scale). If a participant assigned a higher score to the target item, it is indicated that the partitive reading allows recycled objects to be counted multiple times; if not, it is indicated that the partitive reading did not allow recycled objects to be counted more than once.

In addition, a control item is included in each scenario. In Figure 11, the control item expressed that there were 30 passing events that involved cargo ships. Obviously, it was acceptable in the scenario. Judging this item acceptable indicated that a participant was aware of the fact that 10 cargo ships passed through the port twice.

The scenario depicted in Figure 12 supported the non-partitive reading. The first sentence of the scenario said that last year there were 10 thousand events in which a ship passed through Qianshan Port. Among these events, 3000 involved cargo ships, while the other 7000 passenger ships, as conveyed by the second sentence. The third sentence expressed that several cargo ships passed through Qianshan port more than once. They were recycled objects. This scenario did not provide the total number of cargo ships in the discourse. Hence, the percentage in the target item could only be understood as the proportion of cargo ships out of all the ships that passed through Qianshan Port, which is the non-partitive reading.

Scenario
<p>1. Běihǎi shì gòng yǒu 100-sōu huòlún. Beihai city in.total have 100-cl cargo.ship</p> <p>2. Qùnián, yǒu 20-sōu huòlún cóng Shēnzhèn gǎng tōngxíng. last.year have 20-cl cargo.ship through Shenzhen port pass</p> <p>3. Qízhōng yǒu 10-sōu tōngxíng-le liǎngcì, qíyú 10-sōu tōngxíng yíci. among.them have 10-cl pass-asp twice other 10-cl pass once</p> <p>Translation: Beihai City has 100 cargo ships. Last year, 20 of the cargo ships passed through Shenzhen Port. Among them, 10 passed through the port twice, while the other 10 only once.</p>

I. Is the following sentence [target] acceptable based on the scenario?

Qùnián, Shēnzhèn gǎng tōngxíng-le 30% de Běihǎi huòlún.
last.year Shenzhen port pass-asp 30% de Beihai cargo.ship
'Last year, 30% of the Beihai cargo ships passed through Shenzhen Port.'

0	1	2	3	4	5	6
Completely unacceptable			Marginally acceptable			Completely acceptable

II. Is the following sentence [control] acceptable based on the scenario?

Qùnián, Shēnzhèn gǎng tōngxíng-le 30 cì Běihǎi huòlún.
last.year Shenzhen port pass-asp 30 time Beihai cargo.ship
'Last year, there were 30 times in which a Beihai cargo ship passed through Shenzhen Port.'

0	1	2	3	4	5	6
Completely unacceptable			Marginally acceptable			Completely acceptable

Figure 11: A sample scenario (IS) supporting the partitive reading

All the numbers included in the scenario were about the quantities of events, indicated by the use of the event classifier *cì*. If a participant understood the target item as 'the events in which a cargo ship passed through Qianshan Port made up 30% of all the events in which a ship passed through Qianshan Port', s/he would calculate the proportion by dividing 10000 by 3000. Note that s/he shouldn't care about the identities of the cargo ships involved in these events. Therefore, the participant should assign a higher score to the target item.

A control item was also included in the scenario. This control item involved the quantity of individual ships. It said that there were 3000 different cargo ships passing through Qianshan Port. It cannot be true in the scenario. In particular, there were 3000 passing events involving a cargo ship, but several cargo ship passed through the port more than once. So, actually less than 3000 different cargo ships passed through Qianshan Port last year. This control item was also included to make sure that a participant notices the recycled objects.

Scenario	
1. Qùnián Qiánshān gǎng tōngxíng chuánbó yíwàn cì. last.year Qianshan port pass ships 10.thousands time	
2. Qízōng sānqiān cì shì tōngxíng huòlún, háiyǒu qīqiān cì tōngxíng kèlún. among 3000 time be pass cargo.ship also 7000 time pass passenger.ship	
3. Ērqǐ yǒu jǐ-sōu huòlún hái tōngxíng-le bùzhǐ yí cì. and have several-cl cargo.ship even pass-asp not.just one time	
Translation: Last year, 10000 ships passed through Qianshan Port. More specifically, there were 3000 times in which a cargo ship passed through the port, while there were 7000 times in which a passenger ship did. Several cargo ships passed through the port more than once.	

I. Is the following sentence [target] acceptable based on the scenario?

Qùnián, Qiánshān gǎng tōngxíng-le 30% de huòlún.
last.year Qianshan port pass-asp 30% de cargo.ship

0	1	2	3	4	5	6
Completely unacceptable			Marginally acceptable			Completely acceptable

II. Is the following sentence [control] acceptable based on the scenario?

Qùnián, Qiánshān gǎng tōngxíng-le 3000-sōu bùtóng de huòlún.
last.year Qianshan port pass-asp 3000-cl different de cargo.ship
'Last year, 3000 different cargo ships passed through Shenzhen Port.'

0	1	2	3	4	5	6
Completely unacceptable			Marginally acceptable			Completely acceptable

Figure 12: A sample scenario (ES) supporting the non-partitive reading

Participants The participants of this task were the same as those in Task 1.

Results All the 63 participants who participated in Task I also participated in Task II. Recall that three groups of participants were identified based on their performance in Task I. I discuss their performance in Task II below.

28 out of the 35 participants in Group I rated the control items appropriately. That is, they assigned a rating above 4 to the controls in the ISs and a rating below 2 to the controls in the ESs. In other words, they were aware of recycled objects. We summarize the results from the 28 participants in Figure 13a. First, there is a sharp contrast between ES and IS, with the former rated significantly higher than the latter. The red diamonds indicate group means—4.13 for ES and 1.06 for IS. Since this group of participants had been diagnosed to have a consistent non-partitive in Task I, it was expected that they would count recycled objects more than once in ES, but not so in IS. The results from Task II largely confirmed this expectation.

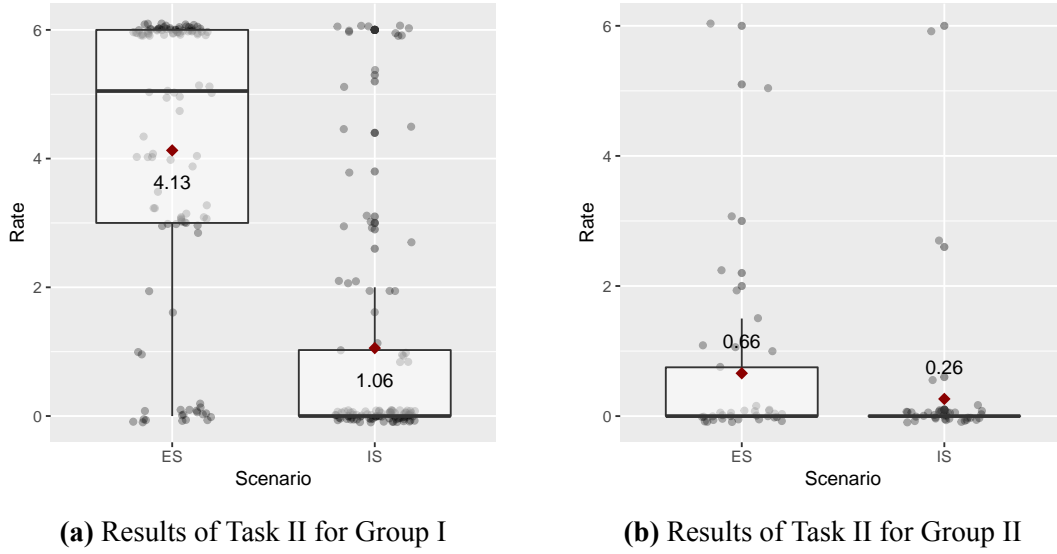


Figure 13: Results of Task II

To confirm whether the scenarios played significant roles in determining the ratings of the target items, I fitted a linear mixed effects model to the data using the maximum likelihood method and Satterthwaite's method for t-test. Rating was entered as the dependent variable and Scenario (ES vs. IS) was entered as the only fixed effect. Participant and Item were included as random effects. Participant further had a random slope for Scenario. (Formula: $\text{Rate} \sim \text{Scenario} + (1 + \text{Scenario} | \text{Participant}) + (1 | \text{Item})$) The result is shown in the following table. The model suggested that the effect of scenarios was very significant ($p < 0.001$).

	β	SE	df	t	p
(Intercept)	4.1277	0.4163	21.0095	9.914	<0.001 ***
ScenarioIS	-3.0723	0.4970	14.3745	-6.181	<0.001 ***

Nine out of the ten participants in Group II passed the control items in Task II. Since these participants lack the non-partitive reading in Task I, it was expected that they also did not allow counting recycled objects in Task II. The performance of these participants in Task II, illustrated in Figure 13b, indeed confirmed the expectation. This group of participants rejected both the ES scenario and the IS scenario: the means for ES and IS are 0.66 and 0.26, respectively.

A.3 Discussion

The online survey shows that the non-partitive reading is available for native speakers of Mandarin. Nevertheless, individual variation indeed exists. Some native speakers seem to reject the non-partitive reading. The reason behind the individual variation is not clear. One way to address this point is to find out whether or not these native speakers can easily perceive the event-related reading of numeral phrases and whether or not the covert focus movement is available in their grammar. I leave these tasks for future study. In addition, for the native speakers who accept both the non-partitive reading and the partitive reading, they count recycled objects more than once in the former,

and count them only once in the latter. These results confirm the contrast between the non-partitive reading and the partitive reading shown in Section 2.1.

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