# German measurement structures: Case-marking and non-conservativity*

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**Abstract** This paper addresses the syntactic and semantic analysis of nominal measurement structures like *two cups of black coffee* in German. German measurement structures allow the case-marking on the substance noun phrase *black coffee* to vary: it can appear in genitive case, or in the same case as the measure noun *cup*. While the choice of case generally does not appear to have semantic import, we show that a semantic distinction does arise with relative measures like *percent*. Moreover, one of these interpretations serves as a *prima facie* counterexample to Keenan & Stavi's (1986) famed *conservativity hypothesis* of DP quantification, as the quantification appears to be non-conservative. We provide an overall analysis of German measurement structures and show how a syntactic-semantic account building on the proposal of Ahn & Sauerland (2017) makes the right predictions and, coincidentally, accords with the conservativity hypothesis.

**Keywords:** measurement, proportional, juxtaposition, nominals, conservativity, quantification, mereology, degree semantics

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## 1 Introduction

In this paper we offer an analysis of *measurement structures*—a class of complex nominal phrases with two nominals N1 and N2, such as the English *three feet*$_{\text{N1}}$ *of rope*$_{\text{N2}}$—in German. Crosslinguistically, we characterize measurement structures following Krifka (1989) and Schwarzschild (2006) as consisting of a numeral or other weak quantifier followed by a *measure noun* N1, and then further material including a *substance noun* N2 and frequently a partitive marker (e.g. English *of*, hence also the term *pseudo-partitive* by Selkirk (1977)) or genitive case.[1]

In addition to genitive/partitive measurement structures, languages like German and Greek (Alexiadou et al. 2007) also allow a second kind of measurement structure in which N1 and N2 agree in case. These two types of measurement structure are illustrated for German in (1):

(1) Genitive and case-matching structures in German (Wöllstein 2016: p. 993, glosses and translations our own):

a. **Genitive N2:**

Der Bericht führt eine erstaunliche Anzahl neuer
the report leads an.ACC amazing.ACC number.ACC new.**GEN**
Projekte.
projects.**GEN**

'The report lists an amazing number of new projects.'

b. **Case-Matching N2:**

Der Bericht führt eine erstaunliche Anzahl neue
the report leads an.ACC amazing.ACC number.ACC new.**ACC**
Projekte.
projects.**ACC**

'The report lists an amazing number of new projects.'

Various terms have been used for these two types of structure. For example, Wöllstein (2016) uses *partitiver Genitiv* ('partitive genitive') and *partitive Apposition* ('partitive apposition'), while Zifonun et al. (1997) use the term *Numerativkonstruktion* ('numerative construction') for both. In order to remain maximally theory-neutral in

1 The linear order of N1, N2, and other elements may vary across languages. We understand *followed* to mean *preceded* in languages with the reverse word order, but in this paper we are exclusively concerned with languages that have the word order described in the main text.

our naming convention, we will follow Alexiadou et al. (2007) in adopting the terms *genitive* and *juxtaposed* measurement structure.

The syntactic distinction in (1) appears to be semantically inert, as (1a) and (1b) have the same truth conditions. Thus, prior to Sauerland (2014b), genitive and juxtaposed structures were not distinguished in detail: for example, Wöllstein (2016) treats the two as purely morphological variants. But when we turn to proportional measure nouns like *Drittel* ('third') and *Prozent* ('percent'), in contrast to non-proportional (hereafter *absolute*) measure nouns like *Anzahl* ('number'), differences in interpretation between genitive and juxtaposed structures come to the fore. The contrast in (2) exemplifies the dramatic semantic difference between genitive and juxtaposed structures with proportional measure nouns:[2]

(2) Semantic distinction between genitive and juxtaposed measurement structures with proportion nouns (based on Ahn & Sauerland 2017: p. 219):

a. Dreißig Prozent der Studierenden arbeiten hier.
thirty percent the.**GEN** students.**GEN** work here
'Thirty percent of the students work here.'

b. Dreißig Prozent Studierende arbeiten hier.
thirty percent students.**NOM** work here
'Thirty percent of the workers here are students.'

Whereas the genitive structure in (2a) has roughly the same meaning as the English *thirty percent of the students*, the juxtaposed structure in (2b) seems to reverse the meaning: rather than asserting that thirty percent of the students work here, it asserts that thirty percent of the workers here are students.[3]

The *reverse* quantification seen in (2b) is fully acceptable in Standard German.[4] Most of the data in this paper are constructed examples, but it is also easy to find attested examples in corpora. The two examples in (3) from web searches both occurred in newspapers, texts that are likely to be checked for grammar. The context in the sources makes clear that the intended reading is the reverse one.

(3) a. Nur zwölf Prozent Frauen sind in der Start-up-Szene tätig.[5]
only twelve percent women are in the start-up-scene working

2 We argue below that the presence or absence of the definite determiner cannot be responsible for the difference in interpretation, but a structural difference related to the case pattern must be the cause.

3 A well-known prior case where a similar reversal phenomenon has been observed is (i) (Westerståhl 1985). We return to the discussion of meaning reversal with vague quantifiers like *many* in the conclusion.

(i) Many Scandinavians have won the Nobel Prize in literature.

4 As far as we have been able to test this up to now, the Isar valley variety of Bavarian is the only German dialect where examples like (2b) are not acceptable. See also footnote 21.

'Only twelve percent of those working in the start-up scene are women.'

b. Ganze 46 Prozent Frauen sind dort … politisch aktiv.[6]
whole 46 percent women are there … politically active
'46% of the people politically active there…are women.'

These judgments were further corroborated by means of a questionnaire study, which is reported in the appendix to this paper, and which illustrates the existence of a semantic contrast between genitive and juxtaposed proportional measurement structures for linguistically naïve native German speakers.

As detailed by Ahn & Sauerland (2015, 2017), such reverse proportional quantification is available in analogous constructions in a variety of languages, including Korean, French, English, Mandarin (see also Li 2018), Greek, and Georgian, among others. An illustration in English can be seen in (4):

(4) a. The company hired thirty percent of the students.
b. The company hired thirty percent students.
(≈ Thirty percent of the company's hirees were students.)

Thus, the phenomenon of reverse quantification with proportional measure nouns appears to be crosslinguistically robust.

The existence of a semantic distinction between genitive and juxtaposed structures with proportional measure nouns, but not with absolute ones, raises several questions about DP-internal syntax-semantics, including the following:

(I) Does the contrast between proportional and absolute measure nouns indicate that structures containing the two should not be syntactically equated?

(II) Is the semantic distinction between genitive and juxtaposed structures attributable to a deeper syntactic distinction?

(III) If proportional measurement structures are syntactically identical to their absolute counterparts, why does the semantic distinction between genitive and juxtaposed structures only arise in the former?

(IV) What do the reverse readings of juxtaposed proportional measurement structures tell us about the famed *Conservativity Hypothesis* of DP quantification (Barwise & Cooper 1981, Keenan & Stavi 1986)?

5 https://www.diepresse.com/1492848/start-ups-manner-sind-selbstbewusster
Last accessed September 8, 2020.

6 https://www.kommunalnet.at/news/einzelansicht/studie-frauen-in-der-burgenlaendischen-kommunalpolitik.html
Last accessed September 8, 2020.

In this paper we seek to address these questions, focusing specifically on what German can tell us about the syntax and semantics of genitive and juxtaposed measurement structures. Our findings and arguments are summarized below.

**Syntactic unity of proportional and absolute** To our knowledge no prior work has argued in favor of a deep structural distinction between absolute and proportional measurement structures, though the presumption of a unified syntactic account has often been left tacit, and much of the relevant literature predates the observation of the crucial data in (2). As mentioned above, Ahn & Sauerland (2015, 2017) do discuss this semantic distinction with proportional measure nouns in a variety of languages (German included), but while they offer an account that treats absolute and proportional measurement structures as syntactically identical, they never explicitly argue in favor of unifying the two in the first place. In Section 2 we provide such arguments for German: after a brief overview of prior work on measurement structures, we show that absolute and proportional measurement structures largely pattern together with respect to number inflection on the measure noun, the presence or absence of an overt determiner in the substance NP/DP, and verbal agreement. Further evidence in favor of such unification will also be seen in Section 3, where we offer our own syntactic analysis of genitive and juxtaposed structures.

**Different constituencies for genitive and juxtaposed structures** There seem to be two viable hypotheses about the origins of the semantic contrast in (2). The first is that this semantic distinction is indeed attributable to a deeper structural distinction between genitive and juxtaposed (proportional) measurement structures. The second possibility is the positing of a lexical ambiguity: there is one *Prozent* that assigns genitive to the substance noun and produces the interpretation in (2a), and one *Prozent* that passes its own case value to the substance noun and produces the reverse interpretation in (2b). The latter hypothesis seems stipulative, especially in light of the aforementioned syntactic unity of proportional and absolute structures: for example, are there also multiple lexical entries for absolute measure nouns, in spite of the lack of semantic distinction? If not, then why do absolute and proportional measurement structures pattern together in the way that they do?

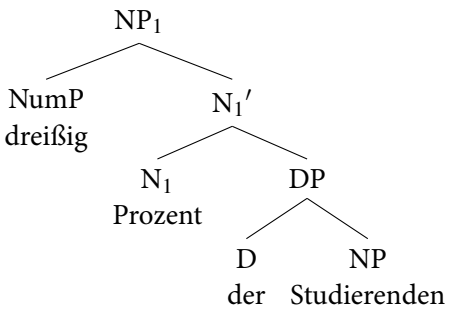
In fact, as will be discussed in detail in Section 3, independent syntactic evidence suggests a deeper structural distinction between genitive and juxtaposed structures. We first discuss the relation between measurement structures and another, seemingly similar construction containing adverbial PPs like *zu sechzig Prozent*:

(5) Zu sechzig Prozent Frauen haben ein iPhone gekauft
at sixty percent women have an iPhone bought
'Sixty percent of iPhone buyers were women.'

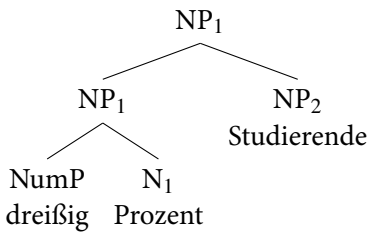
We argue that in spite of their surface-level similarity, adverbial *zu*-PP constructions and measurement structures are fully distinct constructions: the latter form DP-internal NP constituents, in contrast to the former. In addition to ruling out an alternative analysis for juxtaposed structures as parallel to *zu*-PP constructions, this discussion will serve to further highlight various similarities and distinctions between genitive and juxtaposed structures.

We then argue that in genitive structures, the measure noun (*Prozent*) takes the substance DP (*der Studierenden*) as its complement and the numeral (*dreißig*) as its specifier, forming an NP. Juxtaposed structures, meanwhile, feature the numeral and measure noun as an NP constituent to the exclusion of the substance NP; the substance NP then adjoins to it. The proposed analyses can be seen in (6).

(6) a. Genitive




b. Juxtaposed




Thus, the conclusion drawn from Sections 2 and 3 is that while proportional and absolute genitive structures are identical, as are proportional and absolute juxtaposed structures, genitive and juxtaposed structures as broader classes differ from each other in crucial ways.

In Section 4 we show how this difference in the internal structure of genitive and juxtaposed constructions can give rise to the semantic differences observed in (2). Put succinctly, we follow Ahn & Sauerland (2015, 2017) in arguing that in juxtaposed structures, the measure NP (e.g., *dreißig Prozent*) is extracted at LF and takes clausal scope. The reconfigured LF, illustrated in (7) for (2b), then gives rise to quantificational reversal. While our semantic analysis adopts core features from that of Ahn & Sauerland (2015, 2017), it is revised to avoid certain undesirable properties of their account, which we also discuss in Section 4.

(7) $[_{NP_1}$ dreißig Prozent$]$ [ $[_{DP}$ D $[_{NP_1}$ $t_1$ $[_{NP_2}$ Studierende$]]]$ arbeiten hier]

**Semantics of proportional vs. absolute measurement** As for the fact that the semantic difference between genitive and juxtaposed structures arises only with proportional measure nouns, we follow Ahn & Sauerland (2015, 2017) in treating this observation as falling out from differences in the lexical semantics of proportional

and absolute nouns. On our analysis, the structures and operations that lead to quantificational reversal in proportional juxtaposed structures also occur with absolute measure nouns. However, it happens to be the case that with absolute measure nouns, the result is semantically indistinguishable from the interpretation in genitive structures: the semantic distinction between genitive and juxtaposed structures is one that absolute measure nouns are not semantically sensitive to.

**Conservativity** Quantificational determiners like *every* are commonly taken to denote relations between sets: in *Every student left*, for example, *every* relates the set of students (its *restrictor*) to the set of things that left (its *scope*). Conservativity, defined in (8), is a property of some such relations between sets.

(8) A relation $Q$ between sets is **conservative** iff for all $A$ and $B$, $Q(A)(B)$ is equivalent to $Q(A)(A \cap B)$.

For instance, the interpretation of *every* is conservative, as evidenced by the fact that *Every student left* is semantically equivalent to *Every student is a student who left*. In fact, Barwise & Cooper (1981) and Keenan & Stavi (1986) argue that *all* DP quantification is conservative, the so-called *Conservativity Hypothesis*. While the Conservativity Hypothesis has been referred to as one of the "most celebrated semantic universals" (von Fintel & Matthewson 2008), its status is still a topic of considerable ongoing debate among semanticists (Zuber 2004, Keenan & Paperno 2012, Romoli 2015, von Fintel & Keenan 2018, Zuber & Keenan 2019).

The semantic distinction in proportional measurement structures illustrated in (2) is relevant to debates surrounding conservativity because at least by appearances, the quantification involved in the juxtaposed structure in (2b) is non-conservative. To see this, suppose we oversimplify and pretend that there are two lexical determiners: *30%*$^{gen}$, which takes a genitive nominal as its complement and eventually gives rise to the interpretation in (2a), and *30%*$^{jux}$, which takes a case-matching complement and furnishes the reverse interpretation in (2b). The definitions for $[\![30\%^{\text{gen}}]\!]$ and $[\![30\%^{\text{jux}}]\!]$ would be as in (9):

(9) a. $[\![30\%^{\text{gen}}]\!](A)(B)$ is true iff 30% of *A*s are *B*s.
b. $[\![30\%^{\text{jux}}]\!](A)(B)$ is true iff 30% of *B*s are *A*s.

Thus, $[\![30\%^{\text{gen}}]\!]([\![\text{students}]\!])([\![\text{work here}]\!])$ is true iff 30% of students work here, while $[\![30\%^{\text{jux}}]\!]([\![\text{students}]\!])([\![\text{work here}]\!])$ is true iff 30% of the workers here are students, as desired. To test for conservativity, we then see if we get the same result if we replace $[\![\text{work here}]\!]$ with $[\![\text{students}]\!] \cap [\![\text{work here}]\!]$, i.e., the set of students who work here. For *30%*$^{gen}$, things work out nicely: it is indeed the case that 30% of the students work here if and only if 30% of the students are students who work here. But this is not the case for *30%*$^{jux}$: $[\![30\%^{\text{jux}}]\!]([\![\text{students}]\!])([\![\text{students}]\!] \cap [\![\text{work here}]\!])$ is true iff 30%

of the students who work here are students, a near-vacuous interpretation that is very different from the one provided above. Thus, while $[\![30\%^{\text{gen}}]\!]$ is conservative, $[\![30\%^{\text{jux}}]\!]$ is not. And even though this discussion has oversimplified the syntax by treating *30%* as a lexical determiner, the interpretation of proportional juxtaposed structures does present a challenge to a *prima facie* plausible version of the Conservativity Hypothesis: namely, one that is not restricted to lexical determiners, but covers all DP quantification.

But as we show in Section 4, if our analysis of juxtaposed measurement structures is correct then they in fact do not pose the challenge to the Conservativity Hypothesis that they initially appear to. The reason for this is that as mentioned previously, the quantificational reversal effected by juxtaposed structures is a result of the covert extraction of the measure NP (e.g., *dreißig Prozent*) from the DP and its attachment along the clausal spine. The consequence of this reconfiguration is that the DP containing the measure NP's trace has a conservative interpretation on its own, and the seemingly non-conservative interpretation has origins elsewhere in the compositional semantics. In other words, the apparent non-conservative DP quantification seen in proportional juxtaposed measurement structures is only a surface-level phenomenon: at LF, all DP quantification remains conservative.

Finally, Section 5 provides an overview of the results of the paper, as well as some discussion of areas for potential future research.

## 2 Setting the table: absolute and proportional measurement structures

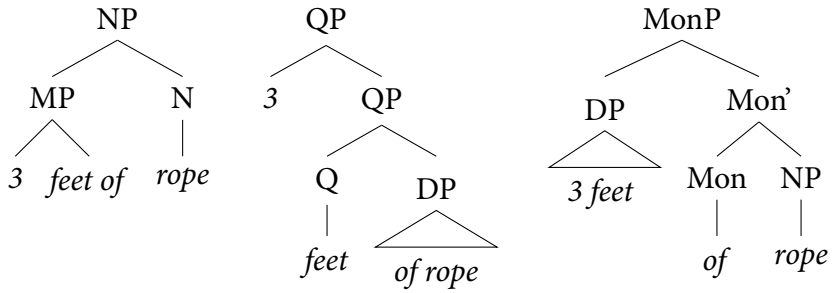
In this section we discuss measurement structures as a broader class, both in general and in German in particular. In Section 2.1 we briefly go over relevant aspects of prior morphosyntactic and semantic work on measurement structures. In particular we discuss in very broad terms the variation in syntactic theories of measurement structures, as well as the potential problems proportional measure nouns create for semantic analysis. In Section 2.2 we focus on German, first discussing some important empirical observations about German absolute measurement structures, and then showing that these observations largely extend to proportional measurement structures. Thus, the evidence points to a unified syntactic-semantic analysis of absolute and proportional measurement structures. In Section 2.3 we summarize the results of this section and discuss the desiderata for a theory of German measurement structures in light of the preceding observations.

### 2.1 A brief overview of prior work

The basic syntax of measurement structures is still under debate, much like with other binominal constructions (see, e.g., Alexiadou et al. 2007, Keizer 2007). Earlier work

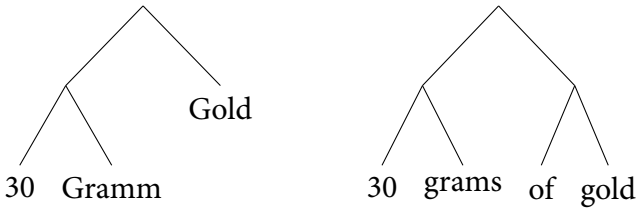
encodes the relationship between the measure noun N1 and the substance noun N2 in three different ways, illustrated in (10): (I) a modifier-modifee relation where N2 projects the complex noun phrase (Jackendoff 1977, Selkirk 1977); (II) a functional head-complement relation within the broad DP where N2 is selected by a functional Q head containing N1 (Löbel 1986, 1990, van Riemsdijk 1998); and (III) a complex phrase projected not by N1 or N2, but by a predicational head like English *of* (Abney 1987: p. 294, Corver 1998, Schwarzschild 2006). Alexiadou et al. (2007) collapse (I) and (II) under the label of *monoprojectional*, since exactly one nominal projects (see also Alexiadou 2014, Tănase-Dogaru 2007). Rothstein (2009), meanwhile, proposes a structural ambiguity between (II) and (III) (see also Partee & Borschev 2012, Keizer 2007; but Zhang 2012).

(10) (I) N2 projects (II) N1 projects (III) *of* projects




On the semantic end, Zifonun et al. (1997) propose an analysis of absolute measurement structures adopted from Krifka (1989). At the heart of the proposal is the idea that measure nouns denote measure functions that map entities to positive real numbers. Specifically, Krifka (1989) assumes that the measure noun forms a constituent with the numeral preceding it, subsequently combining with the substance noun. The proposal is illustrated for German (following Zifonun et al. 1997) and English (following Krifka 1989) in (11).

(11) a. German *30 Gramm Gold* b. English *30 grams of gold*




For these structures, the lexical entries in (12a) for *Gramm/gram* and (12b) for *Gold/gold* are assumed, with ⟦30⟧ simply being the numeral 30:

(12) a. $[\![\text{Gramm/gram}]\!] = \lambda n \lambda x.\ \text{grams}(x) = n$
(where $\text{grams}(x) = n$ iff $x$'s weight is $n$ grams)

b. $[\![\text{Gold}]\!] = \lambda x.\ x$ consists entirely of gold

We assume, following Heim & Kratzer (1998) and others, that in addition to functional application there is a semantic operation of *predicate modification*, which combines two predicates via conjunction.[7] Since [[30 Gramm/grams]] is a predicate true of an individual iff its weight is thirty grams, this predicate combines via predicate modification with [[Gold]], generating a predicate true of an individual $x$ iff $x$ weighs thirty grams and consists entirely of gold.[8] Further composition (including existential closure) can then apply in a complete sentence, so that for example (13a) is interpreted as in (13b).[9]

(13) a. 30 Gramm Gold fehl -en.
30 gram gold be.amiss -PL
'30 grams of gold are missing.'

b. $\exists x[\text{grams}(x) = 30 \wedge \text{gold}(x) \wedge \text{be-amiss}(x)]$

While Krifka's (1989) semantics works well for absolute measurement structures, it does not account for proportional measurement, as (14) illustrates. The denotation of (14a) shown in (14b) is what Krifka's proposal would predict if applied, but this proposal does not capture the relational nature of *percent*: what constitutes thirty percent needs to be determined by taking into account what the whole is of which thirty percent is to be determined. The predicate modification Krifka's semantics postulates for combining the measure term and the substance noun would therefore not generate the correct denotation in the case of proportional measure nouns.

(14) a. 30 Prozent des Golds fehl -en
30 percent the.GEN gold.GEN be.amiss -PL
'30 percent of the gold is missing.'

b. $\exists x[\text{percent}(x) = 30 \wedge \text{gold}(x) \wedge \text{be-amiss}(x)]$ (incorrect)

We thus see that a traditional account like Krifka's (1989) struggles with proportional measurement, an issue that must be resolved by any theory of the syntax-semantics of measurement structures. Furthermore, we will next establish that proportional measurement constructions are not structurally distinct from their absolute

7 Predicate modification is not assumed by Krifka (1989) and Zifonun et al. (1997) as a general compositional principle, but the results are equivalent to the ones obtained here since they build predicate modification into the lexical entry of the measure nouns.

8 Krika's proposal extends to English partitives like *thirty grams of the gold* straightforwardly by the assumption that *of* denotes the mereological part-of relation.

9 Not shown here is exhaustification that applies to the numeral *30* (Spector 2013, Sauerland 2014a).

counterparts, raising further issues already discussed in the introduction: namely, what leads to the semantic distinction between genitive and juxtaposed structures, and why is this apparently confined to structures with proportional measure nouns?

## 2.2 Morphosyntactic unity of measurement structures

The claim that absolute and proportional measurement structures have the same morphosyntactic properties is by no means novel, but so far as we know this stance has only been tacitly assumed, rather than explicitly argued for. The literature on German measurement structures has generally shown no regard for whether the measure noun is (non-)proportional; for example, Kunkel-Razum & Münzberg (2009: p. 984) list the absolute measure noun *Kilogramm* ('kilogram') and the proportional measure noun *Prozent* ('percent') together. However, the quantificational reversal phenomenon in (2b) already shows that proportional measurement structures have interesting syntactic-semantic properties that have not been noticed previously, and that do not surface in an obvious way with their absolute counterparts. This observation could be construed in one of two ways: either proportional and absolute measurement structures are in fact syntactically distinct, in spite of their surface-level similarities; or they are structurally the same, and proportional measurement structures point the way to deeper insights about measurement structures more generally. Given that we adopt the latter view, it is obviously important that we provide explicit evidence for such a unified syntactic-semantic analysis of measurement structures, a task to which we now turn. We will start by introducing some important empirical observations about German absolute measurement structures, and will follow that up by showing that these same observations largely extend to proportional measurement structures.

### 2.2.1 Some observations about German measurement structures

First, let us gather together some empirical observations about absolute measurement structures to give us a reference point for determining whether proportional measurement structures are in fact the same type of syntactic object. Our observations will fall into three categories: (I) grammaticality when the substance NP appears with(out) an overt determiner, (II) morphological number on the measure NP, and (III) verbal number agreement. We will show that (I) only genitive measurement structures allow definite substance NPs, (II) genitive and juxtaposed structures do not differ with respect to number on the measure NP, and (III) genitive and juxtaposed structures do exhibit some differences regarding verbal number agreement.

**Overt determiner with the substance NP** Our first domain of empirical observations concerns the substance NP, and more specifically, whether measurement

structures are grammatical when the substance noun appears with or without an overt determiner. Importantly, genitive and juxtaposed measurement structures differ in this regard. The picture is simplest with juxtaposed structures: in these constructions, the substance NP must be a bare NP, and the introduction of an overt determiner leads to ungrammaticality, as illustrated in (15).

(15) Sie tranken drei Liter (*das) westfälisch -es Bier
they drank three liter (*the.ACC) Westphalian -ACC beer.ACC
'They drank three liters of Westphalian beer.'

With genitive measurement structures, on the other hand, inclusion of an overt determiner is fully grammatical, as shown in (16):

(16) Sie tranken drei Liter des westfälisch -en Bier -es
they drank three liter the.GEN Westphalian -GEN beer -GEN
'They drank three liters of the Westphalian beer.'

However, things get somewhat more complicated when considering where overt determiners can be *excluded* with genitive structures because of a generalization due to Schachtl (1989) (see also the *Genitivregel* ('genitive rule') of Wöllstein 2016: p. 968). She notes that a genitive DP requires a non-nominal exponent of genitive case in the DP, as exemplified by the ungrammaticality of (17):

(17) *? Sie tranken drei Liter Bier -es
they drank three liter beer -GEN

The ungrammaticality disappears when the bare noun *Bieres* is replaced with a structurally complex NP like *westfälischen Bieres*:

(18) Sie tranken drei Liter westfälisch -en Bier -es
they drank three liter Westphalian -GEN beer -GEN
'They drank three liters of Westphalian beer.'

To get around the effects of Schachtl's (1989) generalization, we generally use German examples with either an inflected adjective or a noun such as *Beamte* ('state employee') that inflects like an adjective.

**Morphological number on the measure NP** In terms of morphological expression of number, there appear to be three classes of measure noun: (I) those that *never* inflect for number in measurement structures (even if they can do so outside of measurement structures), such as *Kilo* ('kilogram (NEUT)'); (II) those that *always* inflect for number, such as *Flasche* ('bottle (FEM)'); and (III) those with *optional* number inflection, such as *Glas* ('glass (NEUT)').[10] But regardless of whether the measure noun inflects for

10 As Wöllstein (2016: p. 177–178) discusses, the class of a noun is dependent on it morphological gender, but also on morphophonological factors and the semantic measure–amount–container difference.

number, any adjective modifying the measure noun—such as *gut* ('good') in (19a) and (19b)—must bear the number agreement reflecting the cardinality of the numerals. While (19) illustrates this for juxtaposed measurement structures, the same facts hold for genitive structures.[11]

(19) a. Sie aßen drei gut-e/*-es Kilo / *Kilo-s Fleisch
they ate three good-PL/*-SG kilo / *kilo-PL meat
'They ate three good kilos of meat.'

b. Sie tranken drei gut-e Glas / Gläs-er Bier
they drank three good-PL glass / glass-PL beer
'They drank three generous glasses of beer.'

c. Sie tranken drei *Flasche / Flasch-en Bier
they drank three *bottle / bottle-PL beer
'They drank three bottles of beer.'

With container nouns such as *Glas* ('glass') in (19b), Zifonun et al. (1997) and Grestenberger (2015) show that the presence or absence of number marking on the noun has a semantic effect. For example, only the singular form *Glas* allows a pure amount interpretation, as seen in (20a); the plural only allows the pragmatically odd interpretation involving actual glasses filled with wine and inside of a caraffe. However, this semantic effect is restricted to container nouns that exhibit optional number marking: with non-container nouns and nouns with non-optional number-marking, these effects are not observed. Thus, the optionally number-marked pure measure noun *Liter* ('liter (MASC)') in (20b) does not show any number-dependent semantic effects, while the obligatorily number-marked container noun *Flasche* ('bottle') can have a pure amount interpretation in (20c) in spite of its plural number.

(20) a. Sie kamen mit drei Glas / #Gläs-ern Wein in einer Karaffe.
the arrived with three glass / #glass-DAT.PL wine in a pitcher
'They arrived with the amount of three glasses of wine in a pitcher.'
#'They arrived with three actual glasses of wine inside of a pitcher.'

b. (After Kunkel-Razum & Münzberg 2009: p. 984:)
Sie kamen mit drei Liter / Liter-n Wasser.
they arrived with three liter / liter-DAT.PL water

11 The German adjectival agreement paradigm has many syncretisms. Example (ii) corroborates the analysis of (19a) as involving a plural adjective form, since the adjectival ending *-er* with the neuter noun *Glas* ('glass') must be the Genitive plural of the so-called 'strong' inflection.

(ii) Sie erfreuten sich drei gut-er Glas / Gläs-er westfälischen Bier-es
they enjoyed self three good-GEN.PL glass / glass-GEN.PL Westphalian beer-GEN
'They enjoyed three generous glasses of Westphalian beer.'

'They arrived with three liters of water.'

c. Sie kamen mit drei *Flasche / Flasche-n Wein in einer Karaffe.
They arrived with three *bottle / bottle-PL wine in a pitcher
'They arrived with three bottles of wine in a pitcher.'

In sum, the measure NP fequently displays no number marking, but when it does it must match the cardinality of the numeral. Genitive and juxtaposed measurement structures don't differ with respect to number marking of the measure NP.

**Verbal agreement** In contrast to number marking on the measure NP, German genitive and juxtaposed measurement structures show some differences in verbal agreement patterns when they occupy the subject position. Kunkel-Razum & Münzberg (2009) note that with a plural measure noun and singular substance noun in a juxtaposed measurement structure, both singular and plural verbal agreement are possible, though they describe singular agreement as colloquial in examples like (21a). However, with an adjective modifying the substance noun, exemplified in (21b), both singular and plural verbal agreement seem fully acceptable. In contrast, with genitive measurement structures there is a significant preference for agreement with the plural measure noun, even with an adjective present, as in (21c).

(21) a. (Kunkel-Razum & Münzberg 2009: p. 984:)
Drei Liter Wasser reich { ?-t / -en }
three liter water suffice { ?-SG / -PL }
'Three liters of water suffice.'

b. Drei Liter sauber-es Wasser reich { -t / -en }
three liter clean-NOM water.NOM suffice { -SG / -PL }
'Three liters of clean water suffice.'

c. Drei Liter (des) sauber-en Wassers reich { ?*-t / -en }
three liter (the.GEN) clean-GEN water-GEN suffice { ?*-SG / -PL }
'Three liters of clean water suffice.'

The paradigm in (22) illustrates that just like with adjectival agreement, what is relevant for verbal agreement is semantic number, rather than the morphological number of the measure noun. All of the examples in (22) use the measure noun *Kilo*, which has a plural form (*Kilos*), but is among the class of measure nouns that cannot be pluralized in measurement structures. The generalization from these examples, all of which involve juxtaposed structures in subject position, seems to be as follows: when the semantic number of the measure noun and the substance noun is the same, the verb must show the same number ((22b) and (22c)), but if the two nouns differ in semantic number then agreement with the measure noun is preferred, and agreement with the substance noun is permissible but slightly dispreferred ((22a) and (22d)):

(22) a. Ein gut -es Kilo grüne Bohne -n reich { -t / ?-en }
one good -**SG** kilo green bean -**PL** suffice { -SG / ?-PL }
'One generous kilogram of green beans is sufficient.'

b. Drei gut -e Kilo grüne Bohne -n reich { *-t / -en }
three good -**PL** kilo green bean -**PL** suffice { *-SG / -PL }
'Three generous kilograms of green beans are sufficient.'

c. Ein gut -es Kilo Butter -∅ reich { -t / *-en }
one good -**SG** kilo butter -**SG** suffice { -SG / *-PL }
'One generous kilogram of butter is sufficient.'

d. Drei gut -e Kilo Butter -∅ reich { ?-t / -en }
three good -**PL** kilo butter -**SG** suffice { ?-SG / -PL }
'Three generous kilograms of butter are sufficient.'

In sum, verbs must agree with the semantic number of the measure noun with the genitive measurement structure. The juxtaposed structure, however, allows agreement with either the semantic number of the measure noun or with the substance noun.

**Summary** As a very brief summary of our results thus far, here is what we have found. First, genitive and juxtaposed structures differ in whether the substance noun can (or must) appear with an overt determiner: for juxtaposed structures, the determiner is disallowed, and for genitive structures the determiner is always allowed, and sometimes obligatory. Second, measure nouns differ in their morphological expression of number when they are semantically plural: some never inflect, some always inflect, and for some inflection is optional, occasionally leading to semantic distinctions. And third, genitive and juxtaposed structures behave differently with respect to verbal agreement: with genitive structures as subjects, verbs strongly prefer to agree with the measure noun, but with juxtaposed structures agreement with the measure noun or the substance noun is possible, with a modest preference for the former.

Clearly this is not a complete empirical picture of German measurement structures, and much more data—some of which similarly point toward a unified analysis of absolute and proportional measurement structures—will be discussed later. However, the data discussed above will provide a convenient lens through which to observe this morphosyntactic unity, so we will stick to these for now.

### 2.2.2 Extension to proportional measurement

We now show that proportional measurement structures generally behave like their absolute counterparts in terms of the presence or absence of an overt determiner with

the substance NP, and likewise with respect to verbal agreement. As regards measure NP number inflection, we will show that proportional measure nouns display the same sort of variation seen previously: some cannot inflect, some must inflect, and some show optionality.

**Overt determiner with the substance NP** We start with the presence/absence of an overt determiner with the substance NP. Juxtaposed structures again present the clearest picture: just like with absolute measure nouns, the substance NP must be a bare NP:

(23) Sie tranken dreißig Prozent (*das) westfälisch -es Bier
they drank thirty percent (*the.ACC) Westphalian -ACC beer.ACC
'Thirty percent of what they drank was Westphalian beer.'

As discussed in the introduction, the interpretation that arises here is the "reverse" interpretation (thirty percent of the drunk liquid was beer) and not the conservative interpretation (thirty percent of the beer was drunk). This holds across the board: juxtaposed structures with proportional measure nouns not only *can*, but *must* give rise to reverse interpretations.

With genitive measurement structures, examples with proportional measure nouns look similar, but not quite identical, to their absolute counterparts. In the similarity column is the fact that just like with absolute measure nouns, proportional genitive measurement structures are fully well-formed when the substance noun comes with an overt determiner, as illustrated in (24):

(24) Sie tranken dreißig Prozent des Bieres
they drank thirty percent the.GEN beer.GEN
'They drank thirty percent of the beer.'

Notice again that in the case of genitive measurement structures, the interpretation is necessarily conservative, and a reverse interpretation is unavailable.

However, with respect to when the determiner can be dropped in genitive structures, proportional measure nouns don't play quite so nicely. Recall that with absolute measure nouns, when the substance NP is a bare noun, genitive structures are ill-formed without an overt determiner, but when the substance noun is modified by an adjective determiner-less examples are fully grammatical. Meanwhile, proportional genitive measurement structures are similarly ill-formed with bare substance nouns, but are also quite marked with adjective-modified determiner-less NPs, as seen in (25):

(25) a. * Sie tranken dreißig Prozent Bieres
they drank thirty percent beer.GEN

b. ?? Sie tranken dreißig Prozent westfälisch -en Bier -es
they drank thirty percent Westphalian -GEN beer -GEN.SG
'They drank 30% of (the) Westphalian beer.'

We do not have a full account at hand for why (25b) should be odd, in contrast to its absolute counterpart. That being said, we suspect that the oddity is semantic rather than structural in nature. By all appearances, the substance NP in genitive measurement structures occurs in the syntactic context of a full DP, hence the frequent presence of an overt determiner. If this is true, then in cases where there is no overt determiner there must be a silent one, i.e., a bare mass/plural DP. But cross-linguistically such DPs are known to exhibit a variety of semantic peculiarities and give rise to seemingly diverse readings depending on their environment, as illustrated for English in (26) with the bare plural DP *coyotes*:

(26) a. Coyotes barked at me. *(existential)*
b. Coyotes have four legs. *(generic)*
c. Coyotes are extinct. *(kind-denoting)*

There are well-known attempts at a unified semantic account of bare plural DPs—perhaps most famously, Carlson 1977—as well as the seemingly similar bare mass DPs like *(westfälischen) Bieres* in (25). But regardless of whether such a unified account is possible, in our opinion the oddness of (25b) is more likely to be due to some aspect of the semantics of bare plural/mass DPs than it is to stem from a syntactic distinction between absolute and proportional measurement structures.[12]

As further evidence in favor of such an account, the oddness of proportional genitive measurement structures with bare substance DPs is not universal. A well-formed example can be seen in (27), retrieved from the Internet:[13]

(27) …weil sie die gleichen Probleme habe wie **75 Prozent**
…because she the same problems have.SUBJ as **75 percent**
**deutscher Frauen** …
**German.GEN women** …
'…because she has the same problems as 75 percent of German women…'

The well-formedness of (27) favors an account of (25b) in which the oddness is semantic rather than structural in origin. If this is correct, we observe a full parallel between absolute and relative measurement structures.

12 A reviewer suggests that absolute measures permit a kind interpretation of the substance noun, while this is incompatible with proportional measures since proportions of a kind cannot be established.

13 https://www.abendblatt.de/hamburg/article107201016/Ich-ruehr-in-vielen-Toepfen.html Last accessed October 17th, 2019.

**Morphological number on the measure NP** Recall that when it comes to the morphological expression of number, we noted three broad categories of measure noun: those that cannot inflect for number (e.g., *Kilo*), those that must inflect for number (*Flasche*), and those that show optional number inflection (*Glas*), and that for the latter there were sometimes semantic repercussions for choosing plural inflection on the measure noun. We will now show that proportional measure nouns can be divvied into the same three categories.

In the first category, the proportional measures *Prozent* ('percent (NEUT)') and *Promille* ('permille (NEUT)', i.e., per 1,000) can generally not be marked plural (Wöllstein 2016: p. 175–176), as illustrated for both genitive and juxtaposed structures in (28).[14]

(28) a. Dreißig Prozent { -∅ / *-e } der Studierenden arbeiten hier.
thirty percent { -SG / *-PL } the.GEN students.GEN work here
'Thirty percent of the students work here.'

b. Dreißig Prozent { -∅ / *-e } Studierende arbeiten hier.
thirty percent { -SG / *-PL } students.NOM work here
'Thirty percent of the workers here are students.'

Plural marking on *Prozent* ('percent') improves slightly when the preceding numeral quantifier also carries overt plural morphology. Again, there is no discernible difference between genitive and juxtaposed structures in this regard.

(29) a. Viel -e Prozent { -∅ / *?-e } der Arbeiter sind erkrankt.
many -PL percent { -SG / *?-PL } the.GEN worker are sick
'Several percent of the workers are sick.'

b. Viel -e Prozent { -∅ / *?-e } Arbeiter sind erkrankt.
many -PL percent { -SG / *?-PL } worker are sick
'Several percent of the sick are workers.'

To see examples of the other two categories of measure noun—that is, obligatorily and optionally number-marked nouns—we next turn to fractions. Fractions other than *half* in German all end with the suffix *-tel* and have the same morphological properties, so it suffices to consider the fractions *Hälfte* ('half (FEM)') and *Drittel* ('third (NEUT)'). With the former, plural number marking is obligatory when it is construed with quantity expressions other than one.[15]

14 Wöllstein (2016) note that plural marking can occur on proportional measures when the substance noun is elided; e.g. *einige Prozente sparen* ('some percent-s save').

15 Combining *half* with a quantity other than one but between zero and two is slightly odd because it could always be expressed more easily with another fraction. The examples become most acceptable in a context where comparison on the basis of halves is salient. Concretely, (30a) might be preceded by *One half of the men bought an iPhone* and (30b) by *One half of the iPad buyers were women*.

(30) a. Anderthalb Hälfte { *-∅ / -n } der Frauen haben ein iPhone
one-and-half half { *-SG / -PL } the.GEN women have an iPhone
gekauft
bought
'75% of the women have bought an iPhone.'

b. Anderthalb Hälfte { *-∅ / -n } Frauen haben ein iPhone gekauft.
one-and-half half { *-SG / -PL } women have an iPhone bought
'75% of the iPhone buyers were women.'

Thus, whereas *Prozent* ('percent (NEUT)') falls in the same category as *Kilo* ('kilo (NEUT)') in its universal absence of number-marking, *Hälfte* ('half') patterns with *Flasche* ('bottle') in always inflecting for number.

*Drittel* ('third (NEUT)') and smaller fractions belong to the same category as absolute measures such as *Meter* ('meter (MASC)'), *Liter* ('liter (MASC)'), and *Zentner* ('100-kg (MASC)'): with these measure nouns, number marking can only occur in the Dative (Wöllstein 2016: p. 176).[16] Consider (31), where *Drittel* is part of the dative case-marked experiencer argument of the psych-verb *gefallen* ('please'). Here there is a difference between the genitive and juxtaposed structures: while plural marking is fully optional in the genitive example (31a), it is slighly degraded in the juxtaposed example (31b).[17]

(31) a. Zwei Drittel { -∅ / -n } der Frauen gefiel Conchita.
two third { -DAT.SG / -DAT.PL } the.GEN women please Conchita.NOM
'Two thirds of the women liked Conchita.'

b. Zwei Drittel { -∅ / ??-n } Frauen gefiel Conchita.
two third { -DAT.SG / ??-DAT.PL } women please Conchita.NOM
'Two thirds of those who liked Conchita were women.'

In summary, we have seen that just like with absolute measure nouns, proportional measure nouns fall into three categories: non-inflecting (*Prozent*), obligatorily inflecting (*Hälfte*), and the optionally inflecting in the Dative (*Drittel*). Category classification rather than the absolute/relative distinction determines the number

16 Wöllstein (2016) does not justify analysing the ending *-n* as dative plural rather than as a singular form of the inflection paradigm of adjectives and nouns that inflect like adjectives (see page 12 above). But the comparison of *ein-em Beamte-n* ('a civil servant') vs. *der Beamte* (*'the civil servant'*) with *ein-em Drittel-(*n)* ('a third') vs. *zwei Drittel-(n)* ('two thirds') supports the analysis as plural.

17 We suggest that examples like (31b) with plural morphology are odd due to competition between proportional and non-proportional, container-like interpretations of fractions, which are conventionalized of *Viertel* ('quarter') and *Achtel* ('eighth') as measure of wine. Since non-proportional interpretations only arise in juxtaposed structures and preferably include number inflection, the prediction is that this competition should render the proportional interpretation less available in this case.

agreement of the measure nouns except for the one exception with fractions we noted. Assuming that the exception can be independently explained, the parallel between absolute and relative measures is fully corroborated.

**Verbal agreement** Finally, consider verbal agreement with measurement structures in subject position. Examples (21) and (22) in the previous section showed that absolute measures require verbal agreement with the measure noun in the genitive structure, but allow agreement with either the measure noun or the substance noun in the juxtaposed structure.

Proportional juxtaposed measurement structures conform to the same generalization as absolute measures, as illustrated in (32).

(32) a. Ein Prozent Japaner wohn { -t / ?-en } in Berlin.
one percent Japanese.PL live { -3SG / ?-3PL } in Berlin
'One percent of Berlin residents is/are Japanese.'

b. Sechzig Prozent Butter komm { ?-t / -en } in diesen Teig.
sixty percent butter come { ?-3SG / -3PL } into this dough
'60% of what goes into this dough is butter.'

With genitive proportional measurement structures the possibility of agreement with the semantic number of the measure noun in (33) is also parallel to the absolute counterpart in (21c).[18]

(33) Zwei Drittel des sauberen Wassers reich { ?*-t / -en }
two thirds the.GEN clean-GEN water-GEN suffice { ?*-SG / -PL }
'Two thirds of the clean water suffice.'

**Summary** In sum, the data from agreement and case overwhelmingly confirm the proposal that there is a morphosyntactic unity of measurement structures encompassing both proportional and non-proportional cases. Those instances where

18 Example (33) unlike (21c) requires a definite substance NP as discussed above. Data with indefinite plural count substance nouns may display richer agreement patterns than what (33) shows. For instance, example (18) exhibits a preference for singular agreement even though both the measure and the substance noun are plural. However the judgments in this domain are highly variable and we leave it up to future work to examine whether speakers find clear differences between relative and absolute measures.

(iii) Zwei Drittel deutscher Frauen hat / ?*haben ein iPhone gekauft
two third.SG German.GEN women have.SG / ?*have.PL an iPhone bought
'Two thirds of German women bought an iPhone.'

morphosyntactic unity do not hold appear to be attributable to independent factors. In the next section, we address the syntactic analysis of measurement structures.

## 3 Two structures for measurement structures

The previous section showed that absolute and proportional measurement structures behave in a morphosyntactically parallel fashion in German. Specifically, both allow two main variants: genitive and juxtaposed. We also saw in the previous section that the difference in interpretation between the proportional genitive structure (2a) and juxtaposed structure (2b), repeated below, is not predicted by a straightforward Krifka-style account of measurement structures, as such theories cannot implement proportional measurement in the first place, let alone resolve the central problem of quantificational reversal.

(2) Semantic distinction between genitive and juxtaposed measurement structures with proportion nouns (based on Ahn & Sauerland 2017: p. 219):

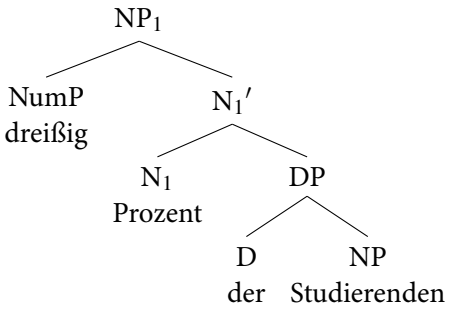
a. Dreißig Prozent der Studierenden arbeiten.
thirty percent the.**GEN** students.**GEN** work
'Thirty percent of the students work.'

b. Dreißig Prozent Studierende arbeiten hier.
thirty percent students.**NOM** work here
'Thirty percent of the workers here are students.'

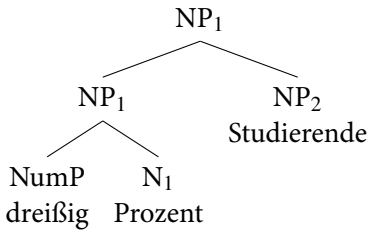
In this section, we will argue that genitive and juxtaposed measurement constructions have different syntactic structures, and in the next section we will show how these syntactic distinctions lead to the observed semantic distinctions in (2). While our proposal is primarily motivated by and framed in terms of proportional measurement structures, given the morphosyntactic parallels it is also intended to apply to absolute measurement structures as well. As a result, we claim that the quantificational reversal phenomenon in (2) applies equally well to absolute as to proportional measurement structures. However, due to features of the lexical semantics of absolute measure nouns like *Kilo*, the pre- and post-reversal truth conditions will turn out to be equivalent when the measure noun is absolute.

The two structures we propose for genitive and juxtaposed measurement structures are shown schematically in (6), repeated below as (34).

(34) a. Genitive




b. Juxtaposed




In both cases, we propose that the measure noun $N_1$ projects an NP, which presumably serves as the complement of a silent indefinite determiner; note that an overt definite determiner is also possible, as seen in (35):

(35) Sie ist von dem einen Liter Bier, den sie getrunken hat, benommen.
she is from the one liter beer the she drunk has affected
'She is affected by the one liter of beer that she drank.'

In both structures the case of $N_1$ is licensed externally, determined by the position the containing DP occupies in the clause. (For the illustration in (34), we assume the external case is nominative.) In the genitive structure, only $N_1$ bears the external case, and the substance DP is assigned genitive case, as commonly occurs with DP complements of nouns. In the juxtaposed structure, meanwhile, the substance NP ($NP_2$) is adjoined to $NP_1$, and the two NPs share the external case assigned to DP (nominative in (34b)). Note also the DP/NP distinction for the substance phrase in the two structures: genitive structures include a full substance DP, while for juxtaposed structures it is only an NP, hence the unavailability of an overt determiner.

In terms of generating the semantic distinctions between the two constructions, the most important difference between (34a) and (34b) is whether the measure noun and the associated number form a constituent excluding the substance noun as in (34b), or not as in (34a). As we previously discussed, both of these possibilities have been proposed in the literature on measurement structures cross-linguistically, as well as for German in particular: Grestenberger (2015) assumes a structure like (34a) for all measurement structures, while Krifka (1989), Zifonun et al. (1997), and Kunkel-Razum & Münzberg (2009) assume a structure similar to (34b) for all measurement structures. But it has not been previously proposed that both structures are available and that they are associated with the genitive/juxtaposed distinction.

Our arguments for the structures in (34) fall into two classes. First, we will present a set of arguments in support of the claim that both genitive and juxtaposed structures form NP constituents headed by the measure noun. While we share this assumption with all previous work on German measurement structures, this is nonetheless an

important step because proportional juxtaposed measurement structures look superficially similar to structures with quantity adverbials—especially with the preposition *zu* ('at') as in *zu sechzig Prozent* ('at 60%')—in which the measure noun is clearly *not* the head of the structure to which it is adjoined. We will show that quantity adverbials can be adjoined to DPs, but that nevertheless the NP analysis is correct for measurement structures. After discussing what genitive and juxtaposed structures share in common—namely, measure noun headedness—we will then turn to those traits that distinguish between the two structures, thereby justifying the syntactic distinction displayed in (34).

### 3.1 Measurement structures as NPs: Contrast with DP adverbials

Both genitive and juxtaposed measurement structures have been regarded as NP constituents in prior work, which has focused on non-proportional measurement. In the previous section we saw evidence that proportional measurement structures are morphosyntactically unexceptional, and thus that syntactic and semantic facts about proportional measurement structures ought to inform any analysis of measurement structures more generally. But given the difficulties traditional analyses face in accounting for proportional measurement, can and should an NP analysis for both genitive and juxtaposed measurement structures still be maintained, or do the facts about proportional measurement force us to adopt a different approach altogether?

The relevance of this question is highlighted by another construction with proportional measure phrases that bears a compelling resemblance to juxtaposed structures: namely, sentences with quantity adverbials like *zu sechzig Prozent* (lit. 'at sixty percent') as in (36) (repeated from (5)), which give rise to similar "reverse" interpretations:

(36) Zu sechzig Prozent Frau-en haben ein iPhone gekauft
at sixty percent woman-PL have an iPhone bought
'Sixty percent of iPhone buyers were women.'

One property of the relevant class of adverbials illustrated by (36) is that they can occur in verb-second clauses together with a nominal phrase as the preverbal constituent. Other adverbials that belong to this class are *größtenteils* ('for the most part'), *ausschließlich* ('exclusively'), and *nur* ('only'). Following Meyer & Sauerland (2009), we assume that these adverbials can adjoin to DP and that this underlies their ability to occur preverbally with a DP as in (36). We will therefore refer to this class of adverbials as *DP-adjoinable adverbials*.[19] Note that other classes of adverbials cannot

19 A reviewer notes that an alternative analysis of *zu*-adverbials is possible, building on work by Fanselow (1987) and others. (iv) below supports the view that *zu*-phrases cannot attach to definite DPs. The reviewer points out that contrasts like that between (36) and (iv) follow if (36) is instead analyzed as remnant VP fronting (Müller 1998) and only indefinite DPs can be part of a remnant VP (Diesing

occur preverbally together with only a nominal in German, as (37) illustrates for the temporal adverb *meistens* ('most of the time').

(37) *Meistens Frau-en haben ein iPhone gekauft
most of the time woman-PL have a iPhone bought

Given the obvious parallels between adverbial *zu sechzig Prozent Frauen* and juxtaposed *sechzig Prozent Frauen*, unifying these two constructions is quite tempting. One could thus say the following: genitive structures are indeed NPs, perhaps as in (34a), or perhaps with some different internal structure. But what we have been calling "juxtaposed" structures—both absolute and proportional, given the morphosyntactic unity of the two—are really adverbial constructions of the sort exemplified in (36), rather than measure-noun-headed NPs like in (34b). We now take on the task of arguing against this analysis and in favor of an NP analysis for both genitive and juxtaposed measurement structures, based on (I) the constituency implications of the case and agreement data discussed in the previous section, (II) adjacency requirements and left dislocation, and (III) co-occurrence with the definite determiner.

### 3.1.1 Case, agreement, and constituency

While *zu*-adverbials share some of the constituency patterns of measurement structures, their agreement and case properties differ substantially. We start with differences in agreement between *zu*-adverbials and juxtaposed structures. While (32) showed that both the measure noun and the substance noun could determine verbal agreement in juxtaposed measurement structures, agreement with DP-adverbials is impossible and as (38) shows agreement must be with the nominal following the adverbial.[20]

1992). (The DP-adverbials mentioned above differ from *zu*-phrases with respect to preverbal position with a definite.)

(iv) *Zu 60 Prozent die Frauen haben ein iPhone gekauft.
at 60 percent the women have an iPhone bought

The choice between these two options does not affect the argumentation in the body of the text, where we show that regardless of the proper analysis of *zu*-adverbials, juxtaposed measurement structures cannot be reduced to adverbial constructions.

20 The slight degradation of (38b) is related to the size of the preverbal constituent. The sentence become fully acceptable if the preverbal constituent is broken up, and still only singular agreement is possible on the verb as shown in (v). (38b) is provided for better comparability with the corresponding measurement structure in (32).

(v) Zu sechzig Prozent komm-t / *komm-en Butter in diesen Teig.
at 60 percent come-SG / *come-PL butter into this dough
'60% of what goes into this dough is butter.'

(38) a. Zu einem Prozent Japaner *wohn-t / wohn-en in Berlin.
at one percent Japanese.PL *live-SG / live-PL in Berlin
'One percent of Berlin residents is/are Japanese.'

b. Zu sechzig Prozent Butter ?komm-t / *komm-en in diesen Teig.
at sixty percent butter ?come-SG / *come-PL into this dough
'Sixty percent of what goes into this dough is butter.'

As for case marking, we have seen that measure nouns in measurement structures must always bear the case assigned to the argument position the DP occupies, while the substance NP/DP can occur either with genitive or matching case, depending on the type of measurement structure. With DP-adverbials the case pattern is different, as (39) shows. First, the noun phrase hosting the DP-adverbial cannot be marked genitive—hence the ill-formedness of (39a)—but must have the case assigned by the verb, as in (39b). This is consistent with the hypothesis that only juxtaposed structures involve DP adverbials, but more problematic is the fact that the equivalent of the measure noun in *zu* adverbials must always bear dative case, as assigned by the preposition *zu* ('at'). Thus, (39c), in which dative case is replaced with structural accusative case, is ill-formed.

(39) a. *Sie tranken zu ein-em Prozent bayrisch-en Bier-es
they drank at one-DAT percent Bavarian-**GEN** beer-**GEN**

b. Sie tranken zu ein-em Prozent bayrisch-es Bier
they drank at one-DAT percent Bavarian-**ACC** beer.**ACC**
'One percent of the drink they consumed was Bavarian beer.'

c. *Sie tranken zu ein Prozent bayrisch-es Bier
they drank at one.**ACC** percent Bavarian-ACC beer.ACC

The agreement properties of measurement structures provide an argument that the measure noun is a head noun of the argument of the verb, at least when the verb agrees with the measure noun and not with the substance noun. Of the different case patterns, examples with the measure noun bearing argument case and the substance noun in genitive case seem to also force an analysis where the measure noun heads the measurement noun phrase. But case agreement in German also can generally be taken as evidence for constituency. This is shown in the literature on quantifier float such as in (40a), and on split topicalization like (40b) (Ott 2012).

(40) a. Diese-n Student-en habe ich gestern all-en geschmeichelt.
these-DAT student-PL have I yesterday all.DAT flattered
'I flattered all these students.' (Merchant 1996: p. 182)

b. Einen Wagen hat er sich noch keinen leisten können.
a.ACC car has he self yet none.ACC afford could

'As for cars, he hasn't been able to afford one yet.'
(van Riemsdijk 1989: p. 4)

Therefore case agreement in juxtaposed structures also corroborates an analysis of measurement structures as a single nominal constituent, especially given that the measurement structures can be the initial constituent of a verb-second clause.

### 3.1.2 Adjacency requirements and left dislocation

Adjacency requirements constitute a second argument for the constituency of measurement structures. Neither genitive nor juxtaposed structures allow the measure noun (phrase) alone to occupy the topic position of the German clause, as shown by (41a) and (41b). In contrast, *zu*-adverbials allow this separation of unit and substance noun as in (41c). Once again, this contrast illustrates that neither measurement structure should be equated with adverbials.

(41) a. * Sechzig Prozent haben hier heute der Kinder übernachtet
sixty percent have here today the.GEN children overnighted
INTENDED: 'Today sixty percent of the children stayed here overnight.'

b. * Sechzig Prozent haben hier heute Kinder übernachtet
sixty percent have here today children overnighted
INTENDED: 'Today children were sixty percent of the people who stayed here overnight.'

c. Zu sechzig Prozent haben hier heute Kinder übernachtet.
at sixty percent have here today children overnighted
'Today children were sixty percent of the people who stayed here overnight.'

The reverse order—topicalization of the substance NP/DP to the exclusion of the measure NP—exhibits a different pattern, illustrated in (42). Only the genitive structure disallows substance NP/DP topicalization, while both juxtaposed and adverbial structures allow such separation.[21]

(42) a. * Der Kinder haben hier heute sechzig Prozent übernachtet
the.GEN children have here today sixty percent overnighted

b. Kinder haben hier heute sechzig Prozent übernachtet
children have here today sixty percent overnighted

21 The few speakers mentioned in fn. 4 who don't fully accept data like (2b) still accept data like (42b). In other words, for these speakers split topicalization is obligatory with juxtaposed measurement structures.

'Today children were sixty percent of the people who stayed here overnight.' / ?? 'Today sixty percent of children stayed here overnight.'

c. Kinder haben hier heute zu sechzig Prozent übernachtet.
children have here today at sixty percent overnighted
'Today children were sixty percent of the people who stayed here overnight.'

But the difference between (42a) and (42b) is a general feature of split topicalization, as previously discussed by van Riemsdijk (1989). For example, we find the same difference with numerals in (43):

(43) a. * Der Kinder haben hier heute drei übernachtet.
the.GEN children have here today three overnighted

b. Kinder haben hier heute drei übernachtet.
children have here today three overnighted
'Today three children stayed here overnight.'

Left dislocation further confirms that the derivation of (42b), but not (42c), involves split topicalization. Split topicalization is generally incompatible with left dislocation, and (44) shows that juxtaposed measurement structures and *zu*-adverbials diverge vis-à-vis the combination of substance-only fronting and left dislocation.[22]

(44) a. * Kinder, die haben hier heute sechzig Prozent übernachtet.
children they have here today sixty percent overnighted

b. Kinder, die haben hier heute zu sechzig Prozent übernachtet
children they have here today at sixty percent overnighted
'Today children were sixty percent of the people who stayed here overnight.'

Thus, while (42b) is apparently a case of split topicalization (hence why (44a) is ungrammatical), the acceptability of (44b) suggests that whatever separates *Kinder* from *zu sechzig Prozent* in (42c) must be some other process altogether.

22 Example (vi) below ought to be a test of left dislocation from genitive measurement structures. The example does not have the conservative interpretation expected for a genitive structure, but is surprisingly quite acceptable, albeit old-fashioned-sounding. But (vi) only permits the reverse interpretation, so it cannot be a genitive measurement structure, but must have some other structure. Because of the stilted character of (vi), we put it aside for now.

(vi) ? Die Kinder, derer haben hier heute sechzig Prozent übernachtet
the children they-GEN have here today sixty percent overnighted
'Today children were sixty percent of the people who stayed here overnight.'

### 3.1.3 Co-occurrence with the definite determiner

Finally, the definite construal of measurement structures strongly supports the constituency of both types of measurement structure. In (35) we already saw an example of an absolute juxtaposed measurement structure with a definite determiner. In fact, both genitive and juxtaposed proportional measurement structures can be part of definite descriptions, as shown in (45a) and (45b), respectively. However, the interpretations of the two are quite distinct.[23]

(45) a. Die sechzig Prozent der Kinder, die hier heute übernachtet
the sixty percent the.GEN children the here today overnight
haben, waren zufrieden.
have were satisfied
'The sixty percent of the children who stayed here tonight were satisfied.'

b. Die sechzig Prozent Kinder, die hier heute übernachtet haben,
the sixty percent children who here today overnight have
waren zufrieden.
were satisfied
'Tonight sixty percent of the people who stayed here were children and these children were satisfied'

DP-adjoined *zu*-adverbials (and other DP-adjoined adverbials) contrast clearly with measurement structures here: as (46a) shows, *zu*-adverbials cannot be part of a definite description, though they can adjoin to a definite DP as in (46b).

23 In both examples, omission of the relative clause renders the example degraded in an out of the blue context. In (45b), this follows because some additional restriction must be provided to select a unique sixty-percent share from all the children. This can also be done by a superlative as in *die schnellsten sechzig Prozent der Kinder* ('the fastest sixty percent of the children') or a prepositional phrase as in *die sechzig Prozent der Kinder aus Deutschland* ('the sixty percent of the children from Germany'), though not as smoothly by just an adjective as in *die deutschen sechzig Prozent der Kinder* ('the German sixty percent of the children'). In (45b), the relative clause seems to play a more important role. Specifically, it might provide a site for reconstruction in a way similar to the analysis of *the few men who came* by Solt (2015b). This correctly predicts that a superlative cannot fill in for the relative clause easily in (vii). However, the prepositional phrase case in (viii) is yet more complicated. We leave resolution of these issues for future work.

(vii) *? Die schnellsten sechzig Prozent Kinder waren zufrieden.
the fastest sixty percent children were satisfied

(viii) Die sechzig Prozent Kinder aus Deutschland waren zufrieden.
the sixty percent children from Germany were satisfied
'Sixty percent of the children come from German and the German children were satisfied.'
'Sixty percent of the Germans were children and the German children were satisfied.'

(46) a. * Die zu 20 Prozent Kinder, die hier heute übernachtet haben, waren
the to 20 percent children the here today overnight have were
zufrieden.
satisfied

b. Zu 20 Prozent die Kinder, die hier heute übernachtet haben, waren
to 20 percent the children the here today overnight have were
zufrieden.
satisfied
'20% of the people who were satisfied were the children that stayed here today overnight.'

In summary, facts pertaining to case assignment, verbal agreement, movement, and co-occurrence with the definite determiner show uniformly that genitive and juxtaposed measurement structures form NP constituents, in contrast to *zu*-adverbials.[24]

### 3.2 Internal constituency of proportional measurement structures

In (34), we proposed two differences in internal constituency between genitive and juxtaposed measurement structures. One was that the substance noun can project a DP in genitives, but only an NP in juxtaposed structures. The other was that the substance DP is a complement of the measure noun in genitives, but the substance NP is an adjunct to the full measure NP in juxtaposed structures.

We already saw clear evidence in favor of the first conclusion in the previous section: in genitive structures and only genitive structures, the substance NP can appear with an overt determiner. The availability of an overt determiner in genitive structures obviously points to the presence of a determiner, and while the unavailability of an overt determiner in juxtaposed structures doesn't necessarily entail the absence of a determiner altogether, at least as a first hypothesis a bare NP seems more plausible than a DP with obligatorily silent determiner.[25]

24 Data from scope reconstruction discussed by Sauerland (2014b) further point toward this conclusion.

25 While the substance noun in genitive structures clearly occurs within the environment of a DP, other principles such as as the partitive constraint (Ladusaw 1982) and the Genitive rule (Wöllstein 2016: 968) further constrain what DPs can occur in this position:

(ix) ? Sechzig Prozent einiger Studenten sind angenommen worden
sixty percent some.GEN students were accepted PASS
'Sixty percent of some students passed.'

(x) *? Sechzig Prozent ihrer sind angenommen worden
sixty percent them.GEN were accepted PASS
'Sixty percent of them passed.'

The second difference between the two types of measurement structures is more difficult to establish based on morphosyntactic evidence alone, with the best available evidence coming from the split topicalization data in (42) above. If split topicalization involves movement, as argued by van Riemsdijk (1989) and Ott (2012, 2015), then (42) shows that the substance NP of juxtaposed structures is available for this kind of movement, but not the substance DP of genitive structures. The analysis of measurement structures in (34) lends itself to a convenient explanation of these facts when combined with Ott's (2012, 2015) theory of split topicalization. Ott argues that split-topicalization involves movement of a predicative NP from a constituent consisting of a DP and an NP. For example, in the case of (47a), Ott's proposed derivation is as in (47b).

(47) a. Reptilien hatten sie nur eine Schlange
reptiles had they only a snake
'As for reptiles, they only had a snake.' (Ott 2015: ex. (38))

b. [Reptilien]$_{NP}$ hatten sie [[nur eine Schlange]$_{DP}$ *t* ]

Split-topicalization from juxtaposed measurement structures can receive an analogous derivation if the analysis in (34) is correct. For (42b), repeated below, this derivation is illustrated in (48).

(42b) Kinder haben hier heute sechzig Prozent übernachtet
children have here today sixty percent overnighted
'Today children were sixty percent of the people who stayed here overnight.',
?? 'Today, sixty percent of children stayed here overnight.'

(48) [Kinder]$_{NP}$ haben hier heute [$_{DP}$ D [$_{NP}$ [sechzig Prozent]$_{NP}$ *t* ]] übernachtet

Juxtaposed structures and split-topic constructions share a number of important properties. First, in both constructions the two nominals must agree in case. In addition, Ott (2015: fn. 10) points out three important distinctions between split-topic constructions and descriptive appositions such as *Merkel, die Kanzlerin, …* ('Merkel, the chanceleress, …'): only the former (I) allow number mismatches, such as (47a)'s plural *Reptilien* ('reptiles') and singular *Schlange* ('snake'); (II) can be split by topicalization; and (III) disallow the definite determiner in the second (topicalized) NP/DP. Juxtaposed measurement structures share all three traits, as was shown above: they allow number mismatches as in (32), they allow topicalization of the second NP as in (42b), and the second part cannot be definite (illustrated in (15) and (23)).

But there is also an important difference between cases of split-topicalization like (47b) and juxtaposed structures like (48): topicalization is *obligatory* in the former, but only *optional* in the latter, at least for Standard German. Hence, while we've seen many examples of juxtaposed structures without substance NP topicalization in this

paper, (47a) is ungrammatical without topicalization of *Reptilien* ('reptiles'), as seen in (49):

(49) * Sie hatten nur eine Schlange Reptilien
they had only a snake reptiles

We believe that this is a matter of parametric syntax, for two reasons. First, as discussed in footnotes 4 and 21 there appears to be at least one dialect of German in which topicalization of the substance NP is in fact obligatory with juxtaposed measurement structures. And second, we will argue in the next section that the measure noun phrase (e.g., *sechzig Prozent*) in a juxtaposed structure must always be extracted to a position with clausal scope at logical form, due to a semantic type mismatch at its initial merge position.[26] Thus it may be that for both split-topic and juxtaposed measurement structures, there is some condition, holding across dialects, that requires that one of the NPs be extracted and attached to the clausal spine.[27] But for reasons that have yet to be determined, dialects differ in what sorts of movement satisfy this condition. In those dialects that require substance NP topicalization in juxtaposed structures, the movement requirement can only be satisfied by overt topicalization; the covert extraction of the measure NP does not suffice, and so there is always overt topicalization of the second NP in both constructions. In Standard German, meanwhile, covert movement suffices, so that LF-extraction of the measure NP satisfies the movement requirement and renders substance NP topicalization optional rather than obligatory. Split-topic constructions presumably lack an analog to covert measure NP extraction, and so overt topicalization is the only option available in all dialects. However, we can only offer this as a sketch of an account, and must leave a fuller account for future work.

Next we turn to genitive measurement structures. At this point, we mostly adopt the structure in (34) for concreteness. Since genitives do not allow split-topicalization and differ in several other ways from juxtaposed structures, the structure of the former must differ from that of the latter. The structure in (34) is adopted from work by Grestenberger (2015) and Scontras (2014). However, one argument in favor of such an account is the genitive case assigned to the substance DP. If this substance DP is the complement to the measure noun, as in our analysis, the fact that it appears in the genitive case is immediately predicted, since genitive is the case typically assigned to the complements of nouns:

26 The account as it stands does not predict the marginal availability of the conservative interpretation in (42b), but the datapoint can be integrated, for example, by assuming that a silent type-adjusting operator is available.

27 For example, Ott (2015) attributes this movement requirement for split-topic structures to the labeling algorithm: if everything were to stay in place, the labeling algorithm would crash. Ott frames his proposal in terms of PF—hence, movement must be overt in split-topicalization structures—but one might be able to expand it to LF as well.

(50) die Zerstörung der Stadt
the.NOM destruction the.GEN city
'the destruction of the city'

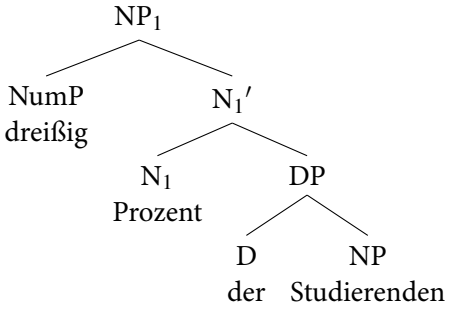
That being said, we do not see any overwhelming evidence in favor of precisely the structure in (34a), and other similar analyses might be feasible. However, a crucial observation that must be accounted for in any theory, and is predicted by our analysis, is that for genitive measurement structures any agreement must be with the measure noun and not the substance noun, as shown in the previous section. Thus, by all appearances the measure noun is the head of the NP in genitive measurement structures; designating the substance DP as the complement of this head is a natural but not logically necessary means of achieving this.

Having put forward our arguments in favor of a structural distinction between genitive and juxtaposed measurement structures, as diagrammed in (34), we next turn to the task of providing a compositional semantics that generates the appropriate interpretations for genitive and juxtaposed measurement structures with both absolute and proportional measure nouns.

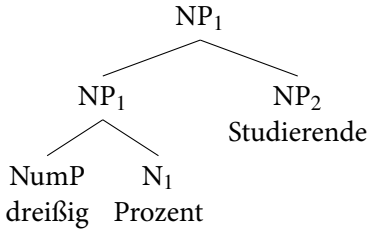
## 4 The semantics of German measurement structures

In light of the previous section, we have landed on the representations in (34), repeated below as (51), for genitive and juxtaposed measurement structures.

(51) a. Genitive




b. Juxtaposed




In this section we show how these structures can give rise to the interpretations associated with them. In the case of proportional measure nouns, the genitive structure will furnish the conservative interpretation in (2a), repeated below as (52a), while the juxtaposed structure will furnish the non-conservative interpretation in (2b), repeated below as (52b).

(52) a. Dreißig Prozent der Studierenden arbeiten hier.
thirty percent the.**GEN** students.**GEN** work here

'Thirty percent of the students work here.'

b. Dreißig Prozent Studierende arbeiten hier.
thirty percent students.**NOM** work here
'Thirty percent of the workers here are students.'

For absolute measure nouns, meanwhile, the two structures will give rise to indistinguishable interpretations.

The structure of this section is as follows. In Section 4.1, we discuss the lexical interpretations assigned to measure nouns. In short, measure nouns and measure phrases denote quantifiers over degrees: *Kilo* quantifies over degrees of weight/mass and *Liter* over degrees of volume, and proportional nouns like *Prozent* are capable of quantifying over various kinds of degrees. In Section 4.2 we discuss the semantics of genitive structures, and in Section 4.3 the semantics of juxtaposed structures. In each case we will go into detail on the proportional side of things by providing an analysis of the examples in (52). We will then show what happens when the proportional measure noun is replaced with an absolute one. Finally, in Section 4.4 we compare and contrast our analysis with that of Ahn & Sauerland (2015, 2017).

### 4.1 The lexical interpretations of measure nouns

Before going into our analysis of genitive and juxtaposed structures, we must first define a lexical semantics for measure nouns. Such nouns have multiple uses outside of measurement structures, with perhaps the most discussed being degree uses, as exemplified by their appearance with gradable adjectives in predicate position as in (53a), as well as in differential comparatives like (53b).

(53) a. My car is two meters tall.
b. My car is three kilos heavier than yours is.

In (53b), for example, *three kilos* is not used to indicate the weight of a particular object, but rather to denote an amount (i.e., degree) of weight that is the difference in weight between our two cars.

There is no established consensus about whether the lexical semantics of measure nouns should start from their measurement use or from their degree use. Krifka (1989), for example, assumes the former, as exemplified by (our version of) his proposed interpretation of *gram*, repeated in (54) below:

(54) $[\![\text{gram}]\!]_{\text{Krifka}} = \lambda n \lambda x.\ \text{grams}(x) = n$

The use of *gram* as a vehicle for measuring individuals is crucially baked into Krifka's semantics for *gram*, as evidenced by its entity argument: after taking a numeral $n$, *gram* takes an individual $x$ and returns true iff $x$ weighs $n$ grams. This contrasts with

degree-based definitions of the sort more common in the literature on adjectives and comparatives. On such definitions, ⟦gram⟧ might be defined as taking a numeral and returning a degree of mass/weight, as in (55):

(55) $[\![\text{gram}]\!]_{\text{degree}} = \lambda n.$ the degree of mass/weight equivalent to $n$ grams

Ahn & Sauerland (2015, 2017), Ionin et al. (2006) model their analysis of measurement structures on an approach analogous to Krifka's, in which measurement of individuals is an essential part of the lexical interpretation of measure nouns (though they modify it in a way that is more conducive to proportional measurement). In this paper we will go the opposite route, building our definitions of measure nouns on their degree uses. However, this leaves open the question of what to do about proportional measurement. Notice that in proportional measurement structures, there is considerable flexibility in the choice of measurement used: while the examples in (52) involve measurement by cardinality, (56) shows that proportional measurement by weight and volume are equally permissible.

(56) In terms of {weight/volume}, 50% of what's in this bowl is rice.[28]

Thus, while *thirty grams* can plausibly be treated as denoting a degree of mass or weight, *thirty percent* cannot simply denote a degree of cardinality (for example). One possible analysis, proposed by Solt (2018), is that phrases like *thirty percent* denote degrees of *proportionality*, with other operators serving to translate between degrees of proportionality and degrees of cardinality, weight, or volume, depending on the environment in which the proportion-denoting phrase occurs. While Solt's proposal may be compatible with the broad analysis adopted in this paper—a matter we leave for future work—we will go a slightly different route. More specifically, we will posit that measure nouns do not *denote* degrees, but *quantify* over degrees. Nouns like *kilo* necessarily quantify over degrees of mass/weight, while nouns like *percent* are flexible in the sorts of degrees they can quantify over. With this in mind, our denotations for German *Kilo* and *Prozent* are provided in (57a) and (57b) below, where for a given degree predicate $D$, $\max(D)$ is the maximal degree of which $D$ is true, while $\max(\text{dom}(D))$ is the maximal degree in $D$'s domain, i.e., the maximal degree for which $D$ returns a defined value (true or false):[29]

(57) a. $[\![\text{Kilo}]\!] = \lambda n \lambda D.\ \max(D) \geq n$ kg.
b. $[\![\text{Prozent}]\!] = \lambda n \lambda D.\ \max(D) \geq \frac{n}{100} \times \max(\text{dom}(D))$

Thus, ⟦dreißig Kilo⟧ is true of $D$ iff the maximal degree for which $D$ is true is at least thirty kilograms, while ⟦dreißig Prozent⟧ is true of $D$ iff the maximal degree for which

28 For more on this use of *in terms of* phrases to fix the choice of measurement, see Pasternak 2019.

29 Our definition for ⟦Prozent⟧, which relies on being able to multiply degrees with numbers, requires that the scale in question be what in measurement theory is referred to as a *ratio scale* (see, e.g., Krantz et al. 1971). For relevant linguistic discussion, see Solt 2015a, Coppock 2020.

$D$ is true is at least thirty percent of the maximal degree for which $D$ is defined. As a result, we rightly predict that ⟦Kilo⟧ can only quantify over degrees of mass/weight (since any quantified-over degree will be compared to a weight degree), but ⟦Prozent⟧ is not so constrained.

We will illustrate how this works with the simple adjectival example in (58):

(58) The glass is fifty percent full.

Following common assumptions, ⟦full⟧ is a relation between degrees $d$ and individuals $x$, true iff $x$'s fullness is at least $d$. This is shown in (59), where $\mu_{\text{full}}$ is the fullness *measure function*, i.e. the function from individuals to their degree of fullness.

(59) $\llbracket \text{full} \rrbracket = \lambda d \lambda x.\ \mu_{\text{full}}(x) \geq d$

Since ⟦fifty percent⟧ is type $(dt)t$, while ⟦full⟧ is type $det$, there is a type mismatch, so *fifty percent* must undergo QR, leading to the LF in (60).[30]

(60) [fifty percent] $\lambda_1$ the glass is $t_1$ full

The trace saturates *full*'s degree argument and *the glass* its individual argument, meaning the post-lambda-abstraction interpretation is as in (61):

(61) $\llbracket \lambda_1 \text{ the glass is } t_1 \text{ full} \rrbracket = \lambda d.\ \mu_{\text{full}}(\text{the\_glass}) \geq d$

Call this degree predicate $D$; ⟦fifty percent⟧$(D)$ is as follows:[31]

(62) $\llbracket (58) \rrbracket = \top$ iff $\max(D) \geq \frac{50}{100} \times \max(\text{dom}(D))$

$\max(D)$ is the maximal degree for which $D$ returns true. This is the degree of fullness of the glass, $\mu_{\text{full}}(\text{the\_glass})$. $\max(\text{dom}(D))$, meanwhile, returns the maximal degree for which $D$ returns a defined value. Since this degree predicate is not explicitly domain-restricted, this must be the maximal degree on the scale of fullness. Thus, the predicted truth conditions are that the fullness of the glass is at least halfway up the scale of fullness, which is intuitively correct.

Now that we have our definitions for measure nouns, we next turn to the task of providing a semantics for genitive and juxtaposed measurement structures.

### 4.2 The semantics of genitive structures

First we will go over genitive structures, using *dreißig Prozent der Studierenden* ('thirty percent of the students') as our example. In genitive structures, the measure noun

30 For types $\alpha$ and $\beta$, type $\alpha\beta$ is the type of functions from $\alpha$ to $\beta$. Types are right-associative, so $\alpha\beta\gamma$ is equivalent to $\alpha(\beta\gamma)$, i.e., $\langle\alpha, \langle\beta, \gamma\rangle\rangle$ in traditional notation.

31 It is more common in the semantic literature to indicate the truth value "true" with 1, rather than $\top$. We opt for the latter because numerals frequently make an appearance in our interpretations, and we wish to avoid any confusion about whether 1 indicates a numeral or a truth value.

*Prozent* takes the substance DP *der Studierenden* as its complement, meaning the two should compose first within the NP. We follow Link (1983) in treating *der Studierenden* as denoting a *plural individual*, the mereological sum of all of the students:

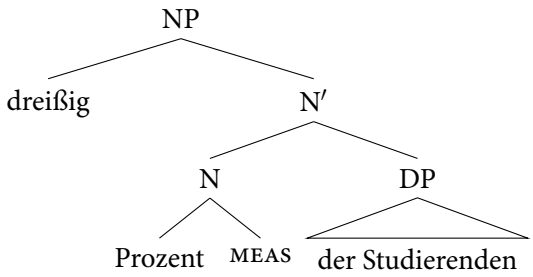
(63) a. $[\![\text{Studierende}]\!] = \lambda x.\ \text{students}(x)$
b. $[\![\text{der}]\!] = \lambda P.\ \bigsqcup P$, where $\bigsqcup P$ is the mereological sum of all $P$s.[32]
c. $[\![\text{der}]\!]([\![\text{Studierende}]\!]) = \bigsqcup(\text{students})$

But this gives us a type mismatch: ⟦Prozent⟧ takes a numeral and returns a degree quantifier (type $n(dt)t$), while ⟦der Studierenden⟧ is type $e$.

This type mismatch is a natural result of our having defined measure nouns based on their degree uses, since a (genitive) measurement structure is more or less the epitome of a measurement use. We will eventually see some advantages to this approach, but in the meantime something must be done to convert *Prozent* from something that quantifies over degrees to something that measures individuals. It is worth emphasizing that in theories that start with a Krifka-style measurement-based definition of measure nouns, the reverse process would have to be done in order to facilitate degree uses of these nouns like in *fifty percent full*. In other words, no matter whether we start from a degree-based or measurement-based definition of measure nouns, something must be done in order to facilitate the opposite use from that for which the noun is defined.

With this in mind, we will posit the inclusion of a head MEAS that adjoins to the measure noun, and that semantically converts it from a degree-use interpretation to a measure-use interpretation. The result in our example can be seen in (64):

(64) Genitive structure (revised):




While the semantic impact of MEAS could also be encoded in the form of a semantic operation of coercion, we "syntacticize" it for the sake of convenience.

Our next step is to define what MEAS actually does. Based on the structure in (64), ⟦MEAS⟧ must take the denotation of a measure noun (⟦Prozent⟧), then a (plural) individual (⟦der Studierenden⟧), then a numeral (⟦dreißig⟧), and return an *et*-type

32 This is slightly different from Link's (1983) formulation in ways that are immaterial for our purposes.

predicate that restricts the determiner taking the NP as its complement. Before defining ⟦MEAS⟧, first we define what will be a useful abbreviation in (65):

(65) For a given measure function $\mu$ and individuals $x$ and $y$, let
$\mu_x[y] = \lambda d : \mu(x) \geq d.\ \mu(y) \geq d$

In other words, for a measure function $\mu$ and individuals $x$ and $y$, $\mu_x[y]$ is a degree predicate defined for degrees no greater than $\mu(x)$, and true of degrees no greater than $\mu(y)$. As a result, if $\mu(x) \geq \mu(y)$ (as will be the case for all of our examples; see fn. 33), then $\max(\mu_x[y]) = \mu(y)$, and $\max(\text{dom}(\mu_x[y])) = \mu(x)$.

We now have enough for a definition of ⟦MEAS⟧, provided in (66). For any $x$ and $y$, $y \sqsubseteq x$ iff $y$ is a mereological part of $x$; in our example $x$ will be the plurality of students, so $y$ must be a sub-plurality of students. $\mu^c$ is a contextually determined measure function; in our example it will be the cardinality measure function.[33]

(66) $\llbracket \text{MEAS} \rrbracket^c = \lambda M \lambda x \lambda n \lambda y.\ y \sqsubseteq x \wedge M(n)(\mu^c_x[y])$

The best way to illustrate how ⟦MEAS⟧ works is by simply going through our example. First, ⟦MEAS⟧ takes ⟦Prozent⟧ as an argument:

(67) $\llbracket \text{MEAS} \rrbracket^c(\llbracket \text{Prozent} \rrbracket)$
$= \lambda x \lambda n \lambda y.\ y \sqsubseteq x \wedge \llbracket \text{Prozent} \rrbracket(n)(\mu^c_x[y])$
$= \lambda x \lambda n \lambda y.\ y \sqsubseteq x \wedge \max(\mu^c_x[y]) \geq \frac{n}{100} \times \max(\text{dom}(\mu^c_x[y]))$
$= \lambda x \lambda n \lambda y.\ y \sqsubseteq x \wedge \mu^c(y) \geq \frac{n}{100} \times \mu^c(x)$

This then takes ⟦der Studierenden⟧ as its next argument:

(68) $\llbracket \text{Prozent MEAS} \rrbracket^c(\llbracket \text{der Studierenden} \rrbracket)$
$= \lambda n \lambda y.\ y \sqsubseteq \bigsqcup(\text{students}) \wedge \mu^c(y) \geq \frac{n}{100} \times \mu^c(\bigsqcup(\text{students}))$

Finally, this takes ⟦dreißig⟧, which denotes the numeral 30, as an argument:

(69) $\llbracket \text{Prozent MEAS der Studierenden} \rrbracket^c(\llbracket \text{dreißig} \rrbracket)$
$= \lambda y.\ y \sqsubseteq \bigsqcup(\text{students}) \wedge \mu^c(y) \geq \frac{30}{100} \times \mu^c(\bigsqcup(\text{students}))$

Assuming that the contextually determined measure function $\mu^c$ is cardinality, what we end up with is a predicate true of $y$ iff $y$ is a part (i.e., a subplurality) of the students, and $y$'s cardinality is at least 30% of that of the students.

We can now move up to the clausal level by analyzing (52a), *Dreißig Prozent der Studierenden arbeiten hier* ('Thirty percent of the students work here'). For our

33 There is a well-known additional semantic requirement for measurement structures: namely that the choice of measurement must track part-whole relations, i.e., the whole must have a greater measurement than its parts (Krifka 1989, Schwarzschild 2006, Rett 2014). We put this requirement aside in this paper, though it can easily be encoded in ⟦MEAS⟧. Note also that if this requirement holds, then if $y \sqsubseteq x$ it must be the case that $\mu^c(x) \geq \mu^c(y)$. This then validates the simplification from $\max(\mu^c_x[y])$ to $\mu^c(y)$.

purposes, issues of tense and modality will be irrelevant, so we will keep our syntactic representations to the $\theta$-domain, i.e., *v*P. Our syntactic structure will be (70):

(70) $[_{vP}\ [_{DP}$ D dreißig Prozent MEAS der Studierenden$]\ [_{v'}\ v\ [_{VP}$ arbeiten hier$]]]]$

For simplicity's sake, we take *v* to be semantically vacuous. Meanwhile, $[\![$arbeiten hier$]\!]$ is an *et*-type predicate true of $x$ iff $x$ works here. Finally, we take D to be a silent indefinite determiner, which contributes existential quantification. Thus, the final predicted truth conditions are as in (71):

(71) $[\![$Dreißig Prozent der Studierenden arbeiten hier$]\!] = \top$ iff
$\exists y[y \sqsubseteq \bigsqcup(\text{students}) \wedge \mu^c(y) \geq \frac{30}{100} \times \mu^c(\bigsqcup(\text{students})) \wedge \text{work\_here}(y)]$

We therefore predict truth iff there is some $y$ that is a subplurality of the students and whose cardinality is at least 30% of that of the students, and who works here. These are indeed the desired truth conditions.

Not much changes when we switch from the proportion noun *Prozent* to the absolute noun *Kilo*. We will use *dreißig Kilo der Äpfel* ('thirty kilos of the apples') as our example. First, $[\![$MEAS$]\!]$ composes with $[\![$Kilo$]\!]$:

(72) $[\![\text{MEAS}]\!]^c([\![\text{Kilo}]\!])$
$= \lambda x \lambda n \lambda y.\ y \sqsubseteq x \wedge [\![\text{Kilo}]\!](n)(\mu^c_x[y])$
$= \lambda x \lambda n \lambda y.\ y \sqsubseteq x \wedge \max(\mu^c_x[y]) \geq n$ kg.
$= \lambda x \lambda n \lambda y.\ y \sqsubseteq x \wedge \mu^c(y) \geq n$ kg.

Notice that in this case, $\mu^c$ must be the weight/mass measure function, since $\mu^c(y)$ must return a degree that can be compared to the degree $n$ kg. This then composes with *der Äpfel* and *dreißig* in unsurprising fashion:

(73) $[\![\text{Kilo MEAS}]\!]^c([\![\text{der Äpfel}]\!])([\![\text{dreißig}]\!]) = \lambda y.\ y \sqsubseteq \bigsqcup(\text{apples}) \wedge \mu^c(y) \geq 30$ kg.

When placed in a clause like *Dreißig Kilo der Äpfel fielen* ('Thirty kilos of the apples fell'), the interpretation is as follows:

(74) $[\![$Dreißig Kilo der Äpfel fielen$]\!] = \top$ iff
$\exists y[y \sqsubseteq \bigsqcup(\text{apples}) \wedge \mu^c(y) \geq 30$ kg. $\wedge\ \text{fell}(y)]$

In other words, we predict truth iff some thirty-kilo subcollection of the apples fell, again as desired.

We have thus seen that our syntactic analysis can be used to generate appropriate interpretations for both proportional and absolute genitive measurement structures. We next move on to juxtaposed structures.

### 4.3 The semantics of juxtaposed structures

We now turn to juxtaposed structures, using *dreißig Prozent Studierende* ('thirty percent students') as our example.

### 4.3.1 NP syntax-semantics

As per our syntactic analysis in (51), juxtaposed structures feature the numeral and measure noun as a constituent to the exclusion of the adjoined substance NP. Thus, in the case of *dreißig Prozent Studierende*, *dreißig Prozent* can compose immediately: ⟦dreißig⟧ denotes a numeral (type $n$), while ⟦Prozent⟧ is type $n(dt)t$.

(75) $\llbracket\text{Prozent}\rrbracket(\llbracket\text{dreißig}\rrbracket) = \lambda D.\ \max(D) \geq \frac{30}{100} \times \max(\text{dom}(D))$

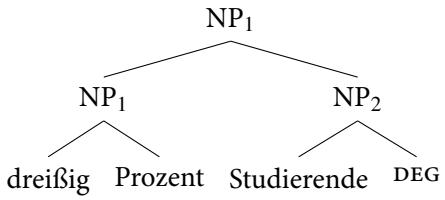
But then we run up against another type mismatch: ⟦dreißig Prozent⟧ is type $(dt)t$, while ⟦Studierende⟧ is type $et$ (more specifically, $\lambda x.\ \text{students}(x)$). We will thus posit a further covert operator, DEG, which adjoins to *Studierende* and introduces a degree argument by way of the contextually determined measure function $\mu^c$:[34]

(76) $\llbracket\text{DEG}\rrbracket^c = \lambda P \lambda d \lambda x.\ P(x) \wedge \mu^c(x) \geq d$

Operators with denotations like (76) are common in the literature on nominal measurement constructions (see, e.g., Schwarzschild 2006, Nakanishi 2007, Rett 2014, Solt 2015b, Wellwood 2015, Pasternak 2019). That being said, much like with MEAS the semantic effects of DEG could equally well be encoded as a purely semantic-pragmatic operation on our analysis—see Rett 2014 for similar discussion—but we encode it syntactically for convenience.

Our revised syntax for juxtaposed measurement structures is thus as follows:

(77) Juxtaposed structure (revised):




Naturally, ⟦DEG⟧ and ⟦Studierende⟧ compose through normal function application:

(78) $\llbracket\text{DEG}\rrbracket^c(\llbracket\text{Studierende}\rrbracket) = \lambda d \lambda x.\ \text{students}(x) \wedge \mu^c(x) \geq d$

This does not immediately resolve the type mismatch with *dreißig Prozent*, but it does change its character. ⟦Studierende DEG⟧$^c$ seeks an argument of type $d$, while ⟦dreißig Prozent⟧ is of type $(dt)t$. This is a familiar sort of type mismatch, and one that is generally resolved via QR: much like with *fifty percent full* above, *dreißig Prozent* undergoes covert movement, leaving a degree-denoting trace that saturates the degree argument of ⟦Studierende DEG⟧$^c$. Thus, in order to get the full picture of the semantics of juxtaposed structures we have to move to the clausal domain and see how the semantics operates after the movement of *dreißig Prozent*.

34 This once again ignores the mereological requirement on measure functions in measurement structures (see fn. 33). But again, this requirement can easily be encoded in the semantics of DEG.

### 4.3.2 Clause-level syntax-semantics and the NoMaxDom problem

To resolve the type mismatch, *dreißig Prozent* is covertly extracted from the DP and attaches along the clausal spine, leading to the LF in (79):[35]

(79) [dreißig Prozent] $\lambda_1$ [[D $t_1$ Studierende DEG] arbeiten hier]

We continue to assume that the determiner is a silent indefinite. The trace $t_1$ saturates the degree argument of ⟦Studierende DEG⟧, generating an *et*-type predicate that restricts the existentially-quantifying D. Thus, the result of semantic composition up to and including lambda-abstraction over the trace can be seen in (80):

(80) $[\![\lambda_1$ [D $t_1$ Studierende DEG] arbeiten hier$]\!]$
$= \lambda d.\ \exists x[\text{students}(x) \wedge \mu^c(x) \geq d \wedge \text{work\_here}(x)]$

This *dt*-type degree predicate—let us call it $D_a$ for short—is true of a cardinality degree $d$ iff at least $d$-many students work here.

$D_a$ is then fed into the $(dt)t$-type ⟦dreißig Prozent⟧, generating the following interpretation:

(81) $[\![\text{dreißig Prozent}]\!](D_a) = \top$ iff $\max(D_a) \geq \frac{30}{100} \times \max(\text{dom}(D_a))$

When computing $\max(D_a)$, the maximal degree for which $D_a$ returns true, there is no problem. This returns the maximal degree $d$ such that some $d$-cardinality plurality of students works here; in other words, it returns the number of students who work here. However, we run into a problem when it comes to $\max(\text{dom}(D_a))$, the maximal degree for which $D_a$ returns a defined value. $D_a$ is a predicate defined for degrees of cardinality and true of cardinalities no greater than the number of students who work here. But since there is no maximal degree of cardinality (unlike, say, fullness), there is no maximal degree for which $D_a$ is defined, meaning that $\max(\text{dom}(D_a))$ is undefined. Our next task is to resolve this problem, which we call the *NoMaxDom problem*, in a way that generates the desired interpretation.

### 4.3.3 Resolving NoMaxDom with focus-derived presuppositions

A semantic observation about proportional juxtaposed structures previously noted by Ahn & Sauerland (2015, 2017) and thus far undiscussed in this paper is that they are semantically *focus-sensitive*: their truth conditions vary depending on focus assignment. This is illustrated by the semantic contrast between the sentences in (82), where a subscripted F indicates assigned focus:

35 This means that on our analysis, juxtaposed structures like inverse linking constructions require scoping out of DP. For arguments that inverse linking can involve extraction of a quantificational constituent from inside to outside a DP, see Sauerland 2005. Sauerland & Bott (2002) and Bobaljik & Wurmbrand (2012) argue that inverse linking in German can involve a scope-assignment process akin to quantifier raising.

(82) a. Dreißig Prozent [westfälische Studierende ]$_F$ arbeiten hier.
thirty percent [Westphalian.NOM students.NOM ]$_F$ work here
'Thirty percent of the workers here are Westphalian students.'

b. Dreißig Prozent [westfälische ]$_F$ Studierende arbeiten hier.
thirty percent [Westphalian.NOM ]$_F$ students.NOM work here
'Thirty percent of the student workers here are Westphalian.'

This semantic sensitivity to focus assignment seems to be specific to *proportional* juxtaposed structures: juxtaposed structures with absolute measure nouns do not give rise to distinct truth conditions depending on focus assignment.

(83) a. Dreißig Kilo [rote Äpfel ]$_F$ fielen.
thirty kilos [red.NOM Apples.NOM ]$_F$ fell
'Thirty kilos of red apples fell.'

b. Dreißig Kilo [rote ]$_F$ Äpfel fielen.
thirty kilos [red.NOM ]$_F$ Apples.NOM fell
'Thirty kilos of red apples fell.'

Thus, not only must our analysis be revised in order to avoid the NoMaxDom problem while generating the desired interpretation, but this resolution must also predict the focus-sensitivity of (only) proportional juxtaposed structures.

We will account for both the NoMaxDom problem and the focus-sensitivity of (proportional) juxtaposed structures by means of a previously proposed connection between focus interpretation and presupposition triggering. Following Rooth (1992), focus-sensitivity is often framed in terms of *focus alternatives*. For a given constituent X, in addition to its "ordinary" interpretation $[\![\mathrm{X}]\!]$ there is also its focus interpretation $[\![\mathrm{X}]\!]_f$, which is a set of interpretations of the same type as $[\![\mathrm{X}]\!]$, but in which focused constituents have their denotations replaced with (perhaps contextually constrained) alternatives of the same type. This is illustrated in (84), where we see that while *Alice likes [Arnie]$_F$* and *[Alice]$_F$ likes Arnie* have the same ordinary interpretation—each denotes the proposition true iff Alice likes Arnie—they have different sets of focus alternatives due to the different assignments of focus:

(84) a. $[\![\text{Alice likes [Arnie]}_F]\!] = [\![\text{[Alice]}_F \text{ likes Arnie}]\!] = \top$ iff Alice likes Arnie.

b. $[\![\text{Alice likes [Arnie]}_F]\!]_f = \left\{ \begin{array}{l} \top \text{ iff Alice likes Arnie,} \\ \top \text{ iff Alice likes Beatrice,} \\ \top \text{ iff Alice likes Charlie,} \\ \vdots \end{array} \right\}$

c. $[\![[\text{Alice}]_{\text{F}} \text{ likes Arnie}]\!]_f = \left\{ \begin{array}{l} \top \text{ iff Alice likes Arnie,} \\ \top \text{ iff Beatrice likes Arnie,} \\ \top \text{ iff Charlie likes Arnie,} \\ \vdots \end{array} \right\}$

Abusch (2010) has argued that there is a general tendency for an utterance of a sentence X to generate a presupposition that at least one of X's focus alternatives is true—that is, it presupposes the truth of the *grand disjunction* of $[\![\text{X}]\!]_f$, $\bigvee[\![\text{X}]\!]_f$.[36] Take, for example, *[Alice]$_F$ likes Arnie*. Here the focus alternatives are all of the form "*x* likes Arnie". The grand disjunction of these alternatives is then tantamount to the claim that *someone* likes Arnie ("Alice likes Arnie or Beatrice likes Arnie or…"). The prediction is thus that while *[Alice]$_F$ likes Arnie* simply asserts that Alice likes Arnie, it presupposes that at least someone likes Arnie. We will not rehash the arguments in favor of this empirical claim; the evidence comes from embedding focus-containing constituents in environments that test for presupposition projection and filtering. Instead, we will show that by adopting this hypothesis, we can avoid the NoMaxDom problem while at the same time making the right predictions about how focus affects the truth conditions of proportional juxtaposed structures.

Suppose that the presupposition of the grand disjunction of focus alternatives is introduced by a head FPRE, which attaches to a proposition-denoting constituent. Furthermore, suppose we adopt the common assumption that presuppositions are encoded as definedness conditions. In this case, the semantic contribution of FPRE can be defined as follows:

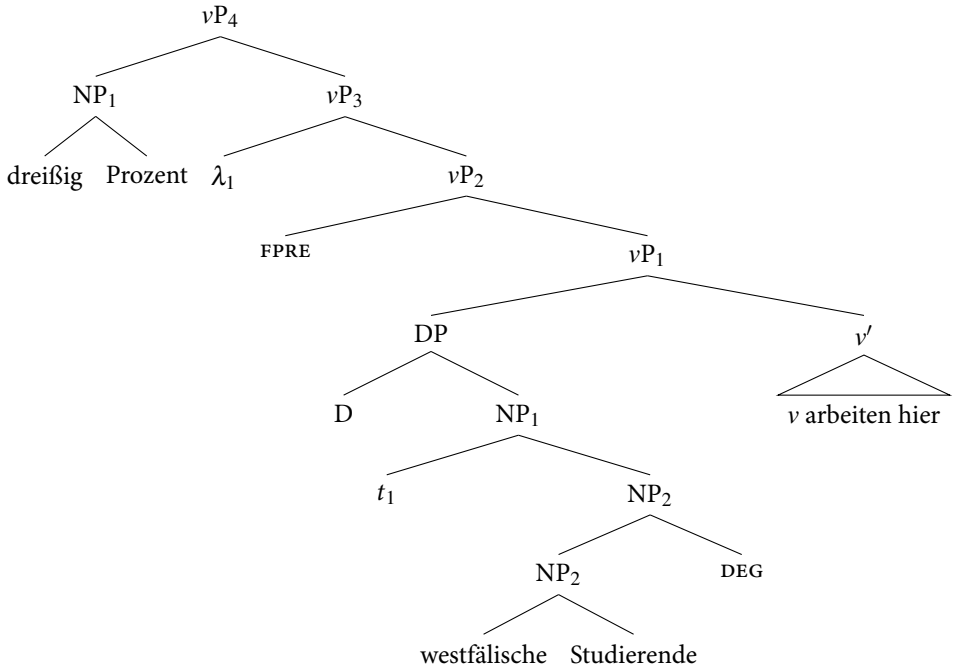
(85) $[\![\text{FPRE X}]\!]$ is defined only if $\bigvee[\![\text{X}]\!]_f$ is true. Where defined, $[\![\text{FPRE X}]\!] = [\![\text{X}]\!]$.

Thus, $[\![\text{FPRE } [\text{Alice}]_{\text{F}} \text{ likes Arnie}]\!]$ will be defined only if someone likes Arnie, and will be true iff Alice likes Arnie.

Now let us go back to the examples in (82). Up to this point we have assumed that *dreißig Prozent* QRs to resolve a type mismatch; since we are assuming only a *v*P for simplicity's sake, this QR will be to the edge of *v*P. Now suppose that immediately before *dreißig Prozent* undergoes this movement and triggers lambda abstraction, FPRE first attaches to the proposition-denoting *v*P. This will lead to the syntactic representation in (86) (temporarily setting aside focus assignment).

36 For prior work making more or less the same empirical claim without framing it in terms of the grand disjunction of Roothian alternatives, see Geurts & van der Sandt 2004.

(86)




We next show that this resolves the NoMaxDom problem and predicts the semantic focus-sensitivity of proportional juxtaposed structures. Let us start with the denotation of $vP_1$. The ordinary interpretation of $vP_1$ is the same regardless of whether focus is assigned to *westfälische* or to *westfälische Studierende*, as shown in (87). Note that since $vP_1$ includes a trace that has not been lambda-abstracted over, the interpretation is sensitive to the variable assignment $g$.

(87) $[\![\text{D } t_1 \text{ [westfälische Studierende]}_\text{F} \text{ DEG arbeiten hier}]\!]^{g,c}$
$= [\![\text{D } t_1 \text{ [westfälische]}_\text{F} \text{ Studierende DEG arbeiten hier}]\!]^{g,c}$
$= \top$ iff $\exists x[\text{westph}(x) \wedge \text{students}(x) \wedge \mu^c(x) \geq g(1) \wedge \text{work\_here}(x)]$
$\approx \top$ iff at least $g(1)$-many Westphalian students work here

But the set of focus alternatives will be different depending on whether focus is assigned to *westfälische* or to *westfälische Studierende*, as shown in (88):

(88) a. $[\![\text{D } t_1 \text{ [westfälische Studierende]}_\text{F} \text{ DEG arbeiten hier}]\!]^{g,c}_f$
$= \{\top$ iff $\exists x[P(x) \wedge \mu^c(x) \geq g(1) \wedge \text{work\_here}(x)] \mid$
$P \in [\![\text{[westfälische Studierende]}_\text{F}]\!]_f\}$
$\approx \{\top$ iff at least $g(1)$-many $P$s work here $\mid$
$P$ is an alternative to *westfälische Studierende*$\}$

b. $[\![\text{D } t_1 \text{ [westfälische]}_\text{F} \text{ Studierende DEG arbeiten hier}]\!]^{g,c}_f$
$= \{\top$ iff $\exists x[P(x) \wedge \text{students}(x) \wedge \mu^c(x) \geq g(1) \wedge \text{work\_here}(x)] \mid$

$$
\begin{aligned}
&P \in [\![[\text{westfälische}]_{\text{F}}]\!]_f\} \\
\approx \{&\top \text{ iff at least } g(1)\text{-many } P \text{ students work here} \mid \\
&P \text{ is an alternative to } \textit{westfälische}\}
\end{aligned}
$$

Put simply, when focus is on *westfälische Studierende* the alternatives are of the form "at least $g(1)$-many $P$s work here", and when focus is just on *westfälische* the alternatives are of the form "at least $g(1)$-many $P$ students work here".

Our next step is to determine the contribution of FPRE. Suppose that among the alternatives for both *westfälische* and *westfälische Studierende* is the vacuously true predicate $\lambda x.\ \top$, or else some predicate that is so weak as to in effect be vacuously true (e.g., $\lambda x.$ human$(x)$ or $\lambda x.$ animate$(x)$). In this case, among the alternatives in (88a) will be (89a), and among the alternatives in (88b) will be (89b).

(89) a. $\top$ iff at least $g(1)$-many individuals work here
b. $\top$ iff at least $g(1)$-many students work here

Importantly, (89a) is weaker than every other alternative in (88a): if at least $g(1)$-many women work here, for example, then it must be the case that at least $g(1)$-many individuals work here. In other words, if any other alternative in (88a) is true, it will also be the case that (89a) is true. As a result, the grand disjunction of the alternatives in (88a) is simply (89a). Similarly, (89b) is weaker than every other alternative in (88b), meaning that the grand disjunction of (88b) is simply (89b).

(90) a. $\bigvee [\![\text{D } t_1 \text{ [westfälische Studierende]}_{\text{F}} \text{ DEG arbeiten hier}]\!]_f^{g,c}$
$= \top$ iff $\exists x[\mu^c(x) \geq g(1) \wedge \text{work\_here}(x)]$
$\approx \top$ iff at least $g(1)$-many individuals work here
b. $\bigvee [\![\text{D } t_1 \text{ [westfälische]}_{\text{F}} \text{ Studierende DEG arbeiten hier}]\!]_f^{g,c}$
$= \top$ iff $\exists x[\text{students}(x) \wedge \mu^c(x) \geq g(1) \wedge \text{work\_here}(x)]$
$\approx \top$ iff at least $g(1)$-many students work here

FPRE then imposes this grand disjunction as a definedness condition (a presupposition), while keeping the ordinary interpretation—which, again, is the same regardless of focus assignment—intact. For readability's sake, from now on we proceed with somewhat more informal statements of the interpretations at hand.

(91) a. $[\![\text{FPRE D } t_1 \text{ [westfälische Studierende]}_{\text{F}} \text{ DEG arbeiten hier}]\!]^{g,c}$ is defined iff at least $g(1)$-many **individuals** work here. Where defined,

$[\![\text{FPRE D } t_1 \text{ [westfälische Studierende]}_{\text{F}} \text{ DEG arbeiten hier}]\!]^{g,c} = \top$ iff at least $g(1)$-many Westphalian students work here.

b. $[\![\text{FPRE D } t_1 \text{ [westfälische]}_{\text{F}} \text{ Studierende DEG arbeiten hier}]\!]^{g,c}$ is defined iff at least $g(1)$-many **students** work here. Where defined,

$[\![$FPRE D $t_1$ [westfälische]$_F$ Studierende DEG arbeiten hier$]\!]^{g,c} = \top$ iff at least $g(1)$-many Westphalian students work here.

Our next step is to lambda-abstract over $g(1)$. Naturally, the definedness condition remains in both cases.

(92) a. $[\![\lambda_1$ FPRE D $t_1$ [westfälische Studierende]$_F$ DEG arbeiten hier$]\!]^c$
$= \lambda d$ : at least $d$-many individuals work here.
at least $d$-many Westphalian students work here

b. $[\![\lambda_1$ FPRE D $t_1$ [westfälische]$_F$ Studierende DEG arbeiten hier$]\!]^c$
$= \lambda d$ : at least $d$-many students work here.
at least $d$-many Westphalian students work here

Let us refer to the degree predicate in (92a) as $D_\alpha$, and the one in (92b) as $D_\beta$. Notice that $D_\alpha$ and $D_\beta$ are true of the same degrees: namely those that do not exceed the cardinality of Westphalian students who work here. But thanks to the focus-sensitivity of FPRE, they have different domains: $D_\alpha$ is defined for degrees not exceeding the cardinality of *individuals* who work here, while $D_\beta$ is only defined for degrees not exceeding the cardinality of *students* who work here. This difference will lead to the difference in truth conditions for (82a) and (82b).

The final step is to feed these degree predicates into [[dreißig Prozent]]. The interpretations are as follows:

(93) a. $[\![$Dreißig Prozent [westfälische Studierende]$_F$ DEG arbeiten hier$]\!]^c$
$= \top$ iff $\max(D_\alpha) \geq \frac{30}{100} \times \max(\mathrm{dom}(D_\alpha))$

b. $[\![$Dreißig Prozent [westfälische]$_F$ Studierende DEG arbeiten hier$]\!]^c$
$= \top$ iff $\max(D_\beta) \geq \frac{30}{100} \times \max(\mathrm{dom}(D_\beta))$

Starting with (93a), $\max(D_\alpha)$ is the maximal degree for which $D_\alpha$ is true, i.e., the number of Westphalian students who work here. Meanwhile, $\max(\mathrm{dom}(D_\alpha))$ is the maximal degree for which $D_\alpha$ is defined, i.e., the number of people who work here. The result is that we predict truth iff the number of Westphalian student workers is at least 30% of the number of total workers: at least 30% of the workers here are Westphalian students. This is the desired interpretation. Meanwhile, for (93b), $\max(D_\beta)$ is the same as $\max(D_\alpha)$, the number of Westphalian students who work here. But this time, $\max(\mathrm{dom}(D_\beta))$ is the number of *students* who work here, not the number of *individuals*. Thus, we predict truth iff the number of Westphalian student workers is at least 30% of the number of student workers. In other words, 30% of the student workers are Westphalian. This is again the correct interpretation. Thus, by combining our analysis of juxtaposed structures with focus-derived presuppositions, the No-MaxDom problem is avoided, and the focus-sensitivity of juxtaposed proportional measurement structures is rightly predicted.

### 4.3.4 Absolute juxtaposed structures

But what about absolute juxtaposed measurement structures? Recall that (I) absolute juxtaposed measurement structures seem to have the same interpretation as their genitive counterparts, and (II) absolute juxtaposed measurement structures do not appear to be focus-sensitive, unlike their proportional counterparts. Both of these observations immediately fall out on our analysis. To see why, we will go through what happens with the juxtaposed-structure-containing sentence *Dreißig Kilo Äpfel fielen* ('Thirty kilos of apples fell').

First, let's see what happens on our analysis if FPRE makes no appearance in this structure whatsoever, meaning *Dreißig Kilo Äpfel fielen* has the structure in (94):

(94) [dreißig Kilo] $\lambda_1$ [[D $t_1$ Äpfel DEG] fielen]

Up to and including lambda-abstraction by $\lambda_1$, the interpretation is as follows:

(95) $[\![\lambda_1$ D $t_1$ Äpfel DEG fielen$]\!]^c$
$= \lambda d.\ \exists x[\text{apples}(x) \wedge \mu^c(x) \geq d \wedge \text{fell}(x)]$
$\approx \lambda d.$ at least $d$-much apples fell

This is then fed into [dreißig Kilo]:

(96) $[\![\text{dreißig Kilo}]\!]([\![\lambda_1$ D $t_1$ Äpfel DEG fielen$]\!]^c)$
$= \top$ iff $\max(\lambda d.\ \exists x[\text{apples}(x) \wedge \mu^c(x) \geq d \wedge \text{fell}(x)]) \geq 30$ kg.
$\approx \top$ iff the max weight $d$ s.t. at least $d$-much apples fell $\geq 30$ kg.
$\approx \top$ iff at least 30 kg. of apples fell

Notice that unlike with proportional juxtaposed structures, there is no NoMaxDom problem: we have a perfectly well-formed interpretation without FPRE. This is because while *Prozent* and other proportional measure nouns are semantically sensitive to not just $\max(D)$ but also $\max(\text{dom}(D))$, *Kilo* and other absolute measure nouns are semantically sensitive only to $\max(D)$. In other words, [Prozent] cares about both the degrees for which a predicate is true and those for which a predicate is defined, while [Kilo] only cares about the former, so the fact that there is no maximal degree of weight does not prevent successful computation with [Kilo].

Notice also that we predict identical truth conditions for genitive and juxtaposed absolute measurement structures: both genitive *dreißig Kilo der Äpfel fielen* and juxtaposed *dreißig Kilo Äpfel fielen* are true iff at least thirty kilos of apples fell. As mentioned in the introduction, this is correct: genitive and juxtaposed measurement structures are semantically differentiated only with proportional measure nouns.

Finally, there is the matter of the non-focus-sensitivity of absolute juxtaposed measurement structures, in contrast to their proportional counterparts. Naturally, when FPRE is excluded no semantic results of focus-sensitivity arise. But what happens if FPRE is included? Recall from our discussion of proportional juxtaposed

measurement structures that the semantic impact of FPRE was in the form of a domain restriction on the derived degree predicate fed to ⟦dreißig Prozent⟧. FPRE had no impact on which degrees this predicate was true of—both with and without it the predicate was true of $d$ iff at least $d$-many Westphalian students work here—but it restricted the domain of this predicate in a focus-sensitive manner. But since ⟦Kilo⟧ only cares about which degrees the predicate is true of, and unlike ⟦Prozent⟧ does not care about the domain of this predicate, the inclusion of FPRE will not have any impact on the predicted truth conditions. Thus, regardless of where focus is placed, and regardless of whether FPRE is included or not, the predicted truth conditions for *dreißig Kilo Äpfel fielen* are true if and only if at least thirty kilograms of apples fell.

Finally, it is worth noting that in spite of initial appearances to the contrary, on our analysis the reverse quantification induced by proportional juxtaposed structures poses no challenge to (the extended version of) the famed Conservativity Hypothesis of Keenan & Stavi (1986), which states that all DP quantification is conservative. This is because our analysis predicts the only quantificational DP to be the one headed by the covert indefinite, from which the measure NP *dreißig Prozent* is extracted. This indefinite contributes existential quantification, which is well-known to be conservative. In other words, our analysis predicts the apparent non-conservativity of proportional juxtaposed structures to be a merely surface-level phenomenon, with all DP quantifiers at LF contributing conservative quantification.

### 4.4 Comparison and contrast with Ahn & Sauerland 2015, 2017

Since our analysis builds on that of Ahn & Sauerland (2015, 2017), it is worth discussing in what ways our treatment deviates from theirs and why. We will argue that our analysis makes several improvements over Ahn & Sauerland's.

As mentioned above, two prominent uses of measure nouns are *measurement* uses, in which they serve to measure individuals, and *degree* uses, in which they serve to denote—or on our analysis, quantify over—degrees. On our approach, the lexical semantics of measure nouns is based on their degree-quantifying use; in genitive structures the switch to a measurement use is effected by a head MEAS (or by an analogous semantic-pragmatic operation), while in juxtaposed structures the degree-quantifying use is retained and the measure NP is extracted to the clausal spine. Ahn & Sauerland (2015, 2017), meanwhile, build their lexical denotations of measure nouns off of their measurement uses. For example, a notationally revised version of their definition of ⟦Prozent⟧ can be seen in (97), where $x \sqcap y$ is the mereological overlap of $x$ and $y$ (the collection of individuals that are part of both $x$ and $y$):

(97) $\llbracket \text{Prozent} \rrbracket^{c}_{\text{A\&S}} = \lambda x \lambda n \lambda P.\ \mu^{c}(x \sqcap (\bigsqcup P)) = \frac{n}{100} \times \mu^{c}(x)$

To see how their analysis works, we will start with genitive structures like *dreißig Prozent der Studierenden*. Much like on our approach, *Prozent* first merges with *der Studierenden*, then takes the numeral as its specifier. However, unlike in our analysis, for Ahn & Sauerland the result of composing *Prozent* with the substance DP and the numeral is not an *et*-type predicate that restricts a covert determiner, but an $(et)t$-type quantifier that takes a predicate $P$ and returns a truth value, i.e., it is the same type normally assigned to quantificational DPs. As a result, on their analysis it must be the case either that the subject in *dreißig Prozent der Studierenden arbeiten hier* ('thirty percent of the students work here') is a bare NP as in (98), or it is a DP with a semantically vacuous determiner head.

(98) $[_{\text{NP}}$ dreißig Prozent der Studierenden] arbeiten hier

Compositionally, the derivation of *dreißig Prozent der Studierenden arbeiten hier* proceeds as in (99):

(99) $[\![\text{Prozent}]\!]([\![\text{der Studierenden}]\!])([\![\text{dreißig}]\!])([\![\text{arbeiten hier}]\!]) = \top$ iff
$\mu^c(\bigsqcup(\text{students}) \sqcap \bigsqcup(\text{work\_here})) = \frac{30}{100} \times \mu^c(\bigsqcup(\text{students}))$

The predicted truth conditions are true iff the cardinality of the plural individual that is the overlap of the students and the collection of individuals that work here is thirty percent of the cardinality of the students.

One apparent advantage to Ahn & Sauerland's analysis over ours is that they do not require the existence of a head or semantic operation MEAS to convert *Prozent* from a degree to a measure use. However, it is not clear that this is an advantage; as noted previously, regardless of whether *Prozent* is lexically degree-quantifying or individual-measuring, something needs to be done to facilitate whichever reading is not lexically encoded. Thus, in order to know whether the lack of MEAS is really an advantage for Ahn & Sauerland, one would have to see how their analysis can handle degree uses such as *fifty percent full*.

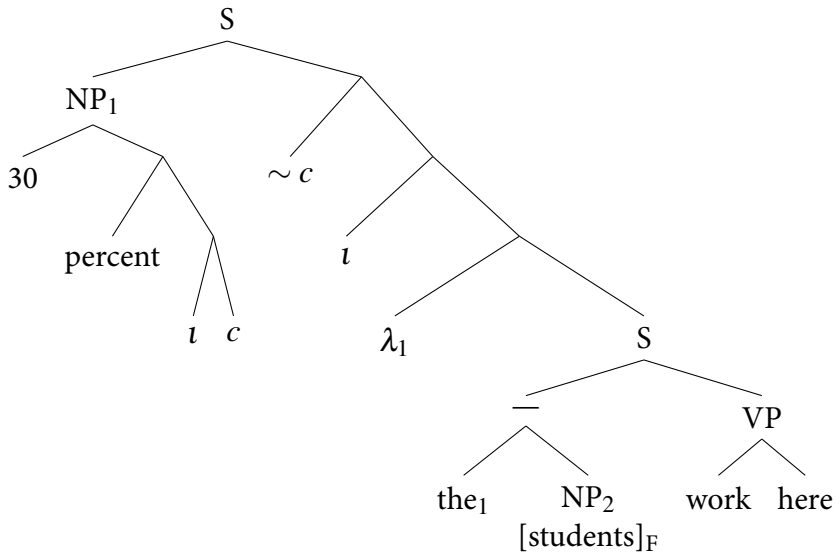
Meanwhile, a *disadvantage* of Ahn & Sauerland's analysis is that the determiner, if there is one, must be semantically vacuous: the quantification over individuals that on our analysis is introduced by the indefinite determiner is on their analysis introduced by the lexical semantics of *Prozent*. While this may be fine for cases in which there is no overt determiner with semantic import, we have already seen at least one case of an overt, semantically contentful determiner with genitive structures: namely, the definite determiner *die* in (45a), repeated below as (100):

(100) Die sechzig Prozent der Kinder, die hier heute übernachtet haben,
the sixty percent the.GEN children the here today overnight have
waren zufrieden.
were satisfied
'The sixty percent of the children who stayed here tonight were satisfied.'

It is not clear how Ahn & Sauerland's analysis could handle (100) while allowing *die* to make its normal referential contribution. But on our analysis (100) is straightforward. The NP *sechzig Prozent der Kinder* denotes a predicate true of pluralities iff they constitute at least 60% of the children, while the relative clause denotes a predicate true of individuals that stayed here overnight. These combine via intersection, generating a predicate true of pluralities that stayed here overnight and that constitute at least 60% of the children. The definite determiner can then serve its usual function of taking a predicate—the denotation of its NP complement—and returning its sum, i.e., the (at least) sixty percent of the children who stayed here overnight.

Next we turn to juxtaposed structures like *dreißig Prozent Studierende*. Again like on our analysis, Ahn & Sauerland propose that in juxtaposed structures, *dreißig Prozent* forms a constituent to the exclusion of *Studierende*, with the former being extracted from the NP and attaching to the clausal spine. However, since on their account measure nouns retain their measurement interpretations in juxtaposed structures, unlike on our account where they have degree-quantifying denotations, some extra syntactic complexities are required in order to generate the desired interpretation. To illustrate, (101) shows the (slightly notationally revised) final derived LF structure Ahn & Sauerland (2017: p. 226) provide for *Dreißig Prozent [Studierende]$_F$ arbeiten hier* ('Thirty percent of the workers here are students'):

(101) Ahn & Sauerland (2017: p. 226):




While for reasons of space we will not go through the whole syntactic-semantic derivation, it will help to discuss the purpose of some of the less intuitive elements of the structure in (101). First, *the$_1$* begins its life as the trace of NP$_1$, $t_1$. However, on the assumption that $t_1$ should denote an individual, we will eventually generate

a type clash: ⟦students⟧ is type *et*, so ⟦$t_1$ students⟧ should be type *t*, which cannot compose with the *et*-type ⟦work here⟧. They fix this with *trace conversion*, a syntactic operation proposed by Fox (2002) within the copy theory of movement, which replaces quantificational determiners at lower copies with bound definite determiners ($the_n$) to generate trace-like bound variable interpretations. While this prevents the type clash and seems to generate the right interpretation (but see below), this comes at a cost: on their analysis, what $the_1$ replaces is not a quantificational determiner like *every*, but $NP_1$. This stipulation requires some significant modifications to the formulation of trace conversion that have otherwise not been motivated.[37]

Second, notice that *percent* has as its complement a constituent consisting of the operators $\iota$ and $c$. These are necessary because Ahn & Sauerland's measurement-based definition of ⟦percent⟧/⟦Prozent⟧ requires an initial entity argument—the same argument saturated by *der Studierenden* in the genitive structure *dreißig Prozent der Studierenden*—which is not saturated by overt material in juxtaposed structures. The denotation of $\iota$ takes a set *P* of individuals and returns the sum of its elements, much like our denotation for the definite determiner. Unsurprisingly, then, the denotation of *c* is a set of individuals, namely, the set of focus alternatives for the sister of $\sim c$ (cf. Rooth 1992). More specifically, since focus is assigned to *students* (*Studierende*), ⟦*c*⟧ will look like (102):

(102) $$[\![c]\!] \approx \left\{ \begin{array}{l} \text{the sum of the students that work here,} \\ \text{the sum of the teachers that work here,} \\ \text{the sum of the administrators that work here,} \\ \vdots \end{array} \right\}$$

Thus, ⟦$\iota$ *c*⟧ will be the sum of members of this set, i.e., the sum of all the people that work here. This should generate the inverted interpretation—thirty percent of the people who work here (⟦$\iota$ *c*⟧) are students who work here—and also predict the focus-sensitivity of juxtaposed structures, since the value of *c* depends on the focus assigned within the sister to $\sim c$.

There are two problems with this analysis, however. The first problem is a stipulation: the constituent $\iota$ *c* must be available to saturate entity arguments for measure nouns when nothing otherwise will. However, we are unfamiliar with any other instance in which ($\iota$) *c* can saturate otherwise unsaturated entity arguments, whether they be arguments of verbs, prepositions, or indeed measure nouns. Thus, the role played by $\iota$ *c* in Ahn & Sauerland's account requires a novel stipulation about the ways in which focus can saturate arguments in the syntax-semantics.

The second problem is that even if we accept Ahn & Sauerland's syntactic stipulations, the structure in (101) does not actually successfully compose, since there

37 For arguments against trace conversion in general, as well as a compositional semantics within the copy theory of movement that obviates it, see Pasternak 2020.

is a type mismatch. The lower S (*the$_1$ [students]$_F$ work here*) denotes a proposition (type $t$), with lambda abstraction via $\lambda_1$ generating a predicate (type $et$) roughly true of any collection of students that works here. The result of lambda abstraction is then fed to $\iota$, which takes this predicate and returns an individual: the sum of all of the students that work here. $\sim c$ does not contribute anything to the compositional semantics directly—its sole purpose is to tell $c$ what constituent's focus alternatives to denote—meaning that the sister of $NP_1$ is type $e$. However, this is not the type of the last argument of Ahn & Sauerland's denotation for ⟦percent⟧: as noted above and shown in (97), the final argument for ⟦percent⟧/⟦Prozent⟧ is not an individual, but an $et$-type predicate, meaning that *30 percent* $\iota$ $c$ cannot compose with its sister. This could perhaps be fixed by removing the $\iota$ immediately above $\lambda_1$, thereby leaving the post-lambda-abstraction predicate intact. But this leads to another problem. As noted before, $c$ denotes the set of focus alternatives for the constituent that is the sister of $\sim c$. Since $c$ has to denote a set of individuals for the analysis to work, it is thus crucial that the sister to $\sim c$ denote an individual (since $[\![X]\!]_f$ is a set of objects of the same type as ⟦X⟧). Thus, $\iota$ must be present above $\lambda_1$ in order for the composition within $NP_1$ to work, while it must be absent in order for $NP_1$ to compose with its sister. Perhaps there is a way to resolve this within Ahn & Sauerland's analysis, but the path forward is not obvious.

By way of contrast, our own analysis of juxtaposed structures does not need the sorts of syntactic and semantic stipulations required for Ahn & Sauerland's analysis. Our analysis of juxtaposed structures requires two elements of syntactic "dark matter" (to quote an anonymous reviewer): DEG and FPRE. But unlike the modifications to trace conversion or the use of $\iota$ $c$ to saturate entity arguments, DEG and FPRE both have very specific, empirically well-grounded motivations entirely independent of juxtaposed structures. As mentioned previously, semantic operators essentially identical to DEG have frequently been proposed in the literature on nominal and verbal measurement constructions—see, for example, *M-Op* in Rett 2014, *Meas* in Solt 2015b, and *much* in Wellwood 2015 and Pasternak 2019. Similarly, as discussed above the observation of focus-derived presuppositions has been independently made in the literature; we encode the derivation of focus presuppositions through a head FPRE, but this could equally well be encoded through some other means. Thus, our analysis of juxtaposed structures avoids the problems of compositionality and stipulation faced by Ahn & Sauerland's analysis.

## 5 Conclusion

In this paper, we have provided evidence that while genitive and juxtaposed measurement structures have identical truth-conditional interpretations with absolute measure nouns, they have differing interpretations with proportional measure nouns.

We have argued that this semantic distinction is born from a structural distinction between genitive and juxtaposed structures: in the former, the substance DP is the complement to the measure noun, while in the latter the substance NP is adjoined to the measure NP, with the latter undergoing QR outside of the DP to a position along the clausal spine. We then provided a compositional semantics for both genitive and juxtaposed measurement structures that generates the right interpretations, correctly predicting a distinction in the case of proportional measure nouns (including focus-sensitivity in juxtaposed structures), with no such distinction with absolute measure nouns. This analysis, which was shown to have multiple advantages over the analysis of Ahn & Sauerland (2015, 2017) on which it is based, also happened to be compatible with the Conservativity Hypothesis, despite first appearances.

As previously mentioned, Ahn & Sauerland (2017) note that non-conservative interpretations of proportional measurement structures can be observed in a wide variety of languages. It is thus natural to wonder how well the analysis of German measurement structures in this paper extends to these other languages. This will require fine-grained analysis of the syntactic structure and semantic interpretation of measurement structures cross-linguistically, promising to generate important insights into the nature of DP-internal syntax-semantics.

The data we discussed with precise proportional measures also provide a novel vantage point to investigate apparent non-conservative readings with vague proportional quantifiers. As we mentioned in footnote 3, English *many* has been widely discussed in this respect in the semantic literature. But, as Solt (2018) also concludes, it's not easy to account for all readings of all proportional quantifiers uniformly. To determine whether and how such a uniform account is possible and desirable, the study of languages other than English and of the structures and interpretations of non-vague as well as vague quantifiers will also be insightful.

## A Corroborating judgments for proportional measurement structures

Informal judgment data indicate that the availability of non-conservative construals is not uniform across German dialects (see fn. 4 above). To corroborate that among Berlin speakers the core judgements are widely shared, we carried out a questionnaire study. The study used a forced-choice paradigm. Our study compared two conditions differentiated only by context: the conservative and the non-conservative context, both of which are illustrated in (103). In both contexts, participants were offered three sentences and the participants were instructed to mark the sentence that offers the best description of the context paragraph. They were asked to always mark exactly one sentence.

As (103) shows, the three alternatives offered belong to the following three target structures: the nominative juxtaposed structure, and the genitive structure both

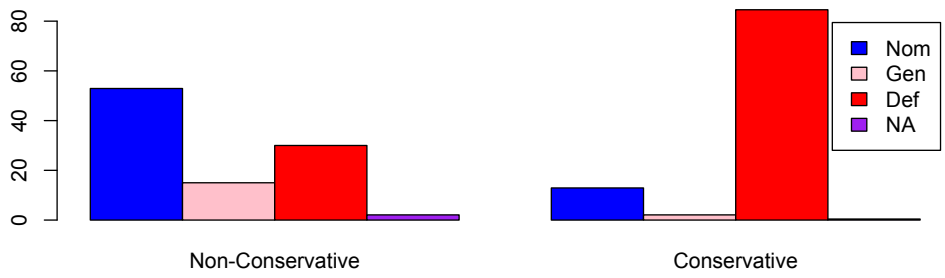



**Figure 1** Result of sentence choice experiment in a non-conservative vs. conservative context in % of all responses.

without and with a definite determiner. We constructed 24 items in total, with no fillers. We used pseudo-randomized lists, wherein both the order of items and the order of the three alternative target sentences varied.

(103) **Non-Conservative Context:** *In Berlin, 60,000 people commute by bike. Of those, 15,000 are civil servants.*

**Conservative Context:** *In Berlin, there are 60,000 civil employees. 15,000 of them commute by bike.*

a. **Nom:** 25 Prozent Beamte fahren mit dem Fahrrad zur Arbeit.
25 percent servant.NOM go with the bike to.the work

b. **Gen:** 25 Prozent Beamter fahren mit dem Fahrrad zur Arbeit.
25 percent servant.GEN go with the bike to.the work

c. **Def:** 25 Prozent der Beamten fahren mit dem Fahrrad zur Arbeit.
25 percent the.GEN Beamte.GEN go with the bike to.the work

Twenty undergraduate students in Berlin participated in the study. Half of the participants received the list in the original order, the other half received it in the reverse order. The result is summarized in Figure 1. In the non-conservative contexts the sentence with juxtaposed structure is most frequently chosen, while in the conservative context that Definite genitive context is most frequently chosen. This result confirms our expectation that speakers prefer the juxtaposed structure with the non-conservative context and the genitive structure in the conservative context.

The results also indicate that the choice is less clear-cut in the non-conservative context, which may relate to greater speaker difficulty in understanding the non-conservative context, higher speaker uncertainty about the interpretation of the juxtaposed structure, or speaker variation. We leave it up to future research to investigate further which combination of these factors contribute to this result.

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