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A Weakly Compositional Analysis of Distance Distributivity in Polish

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1 Introduction

Distance distributivity is a phenomenon where a distributive element such as *each* occurs at some structural distance from the nominal phrase that restricts it, as in *The boys have two apples each*.[1] In this sentence, the distributive element *each* occurs in the object position, while its restriction, *the boys*, is the subject of the sentence. This should be contrasted with the determiner uses of *each*, as in *Each boy has two apples*, where *each* combines directly with its restriction, as other ad-nominal quantifiers do.

There are various terminological conventions in the literature, e.g., Choe 1987 calls such uses of *each* "anti-quantifiers", and Safir and Stowell 1988 call them "binominal". Both terms are suboptimal: much subsequent literature attempts to describe such distributive elements (DEs) as more-or-less ordinary quantifiers (not as special "anti-quantifiers") and it is clear now that DEs in other languages, including German and Polish, do not need two nominal expressions (*the boys* and *two apples* above) but – as shown by Moltmann 1991, 1997 – may quantify over events expressed by verbal constituents (hence, they are not "binominal"). In this paper we adopt the terminology of Zimmermann 2002, who introduced the term

[1] I am grateful for comments from the audience of FASL 23 and, especially, to the two anonymous reviewers. Also the acknowledgements of the accompanying papers Przepiórkowski 2014a,b carry over here. Needles to say, all remaining errors are my own.

"distance distributivity" (DD), and call the nominal phrase DE attaches to (*two apples* above) "distributive share" (DS), and the phrase expressing the set of entities which restrict DE (*the boys* above) – "distributive key" (DK).

It is clear that DD is not a completely uniform phenomenon and constraints on structural relations between DSs (and, hence, DEs which attach to them) and DKs differ across languages. Zimmermann 2002, working within the transformational paradigm of late 1990s, explains these differences in terms of inherent features of DEs and distinguishes two classes of DEs: those that have determiner features and, hence, must be c-commanded by a DP for these features to be licensed, and those that do not have such determiner features. The c-command requirement prevents the former from occurring in the (underlying) subject position, as in the unacceptable English **One student each gave presents to the teachers* (Safir and Stowell 1988: 436, (26a)), while no such restriction is observed in case of the German DE *jeweils* or the Polish DE *po*:[2]

(1) Jeweils ein Offizier begleitete die Ballerinen nach Haus.
DISTR one officer$_{NOM}$ accompanied the ballerinas$_{ACC}$ to home
(German)
'Each ballerina was accompanied home by one officer.'
(Zimmermann 2002: 27, (16))

(2) Z drzew spadło po jabłku. (Polish)
from trees fell DISTR apple$_{LOC}$
'An apple fell from each tree.' (Łojasiewicz 1979: 154)

To the best of our knowledge, Zimmermann 2002 remains the only comprehensive syntactico-semantic analysis of DD of the kind observed in German and Polish. The aim of this paper is to show that Polish data do not comfortably fit the account of Zimmermann 2002 (§ 2) and to introduce a construction which that analysis cannot account for (§ 3). Due to lack of space, an alternative analysis is only sketched here (§ 4), but it is presented in gory technical detail in accompanying papers (Przepiórkowski 2014a,b).

[2] Unlike the binominal *each*, which always follows the DS, *jeweils* usually precedes the DS (Zimmermann 2002: § III.5.3), while *po* always occurs immediately before it.

2 Zimmermann 2002

Various problems, both empirical and theoretical, with earlier accounts of DD such as Choe 1987, Safir and Stowell 1988, Moltmann 1991, 1997 and Link 1998, are discussed and criticised in Zimmermann 2002, so here we only refer to Zimmermann's approach.

While Zimmermann 2002 remains the most comprehensive account of distance distributivity in German and cross-linguistically, it is not without problems. First, as noted by Dotlačil 2012, Zimmermann's assumption that the relation between DS and DK is expressed by a syntactic constituent (e.g., *have* in *Each boy have two apples*) does not always hold. For example, in *Alex and Sasha visited the capitals of three states each* there is no constituent corresponding exactly to *visited the capitals of*.

Second, the careful reader of footnotes will note that Polish (and Slavic in general) fits rather uncomfortably into Zimmermann's account.[3] In particular, it seems unexpected on Zimmermann's analysis that the *po* DE obligatorily precedes DS in Slavic. While a cross-linguistically valid analysis is highly desired, we feel that it should be guided by more detailed investigations into particular languages.

Third, although Zimmermann (2002) seeks to provide an account not relying on LF movement (and gives good arguments against the LF-based analysis of Safir and Stowell 1988), he acknowledges that his analysis must assume such covert movement for some occurrences of *jeweils*, including (1) above (see his § 2.4.2 in ch. V, pp. 271ff.).

Fourth, in the course of providing the details of the syntactico-semantic analysis of DD across languages, Zimmermann (2002) is forced to introduce some non-standard mechanisms and make a number of assumptions contradicting the majority view in the framework hosting the analysis. One such mechanism is the "Type-Triggered λ-Abstraction" (p. 219), a very specific composition rule supplementing the more run-of-the-mill (Bittner 1994, Heim and Kratzer 1998) "Index-Triggered λ-Abstraction" and triggered in some contexts as "a last resort mechanism that only applies if all else fails". Among unusual assumptions there is also one about head

[3] See, e.g., fn. 86 on p. 131, fn. 87 on p. 132 (together with fn. 76 on p. 119). Also aspects of Korean seem problematic, e.g., fn. 83 on p. 134, fn. 98 on p. 143, fn. 21 on p. 276, as well as main text on p. 140.

movement out of adjuncts (fn. 76 on p. 119, but see also fn. 87 on p. 132), and another about event binding within VP (p. 226). Moreover, while putting much emphasis on the compositionality of the proposed analysis, some of its elements are not fully compositional, e.g., the context-driven insertion of various restrictions into the representation of the German DE *jeweils*, e.g., in (176) on p. 232 (with the introduced relation $\in$), in (184) on p. 234 (with the relation $\subseteq$), and in (219) on p. 247 (with a new set variable). Such *ad hoc* mechanisms result in rather different representations of similar sentences (e.g., (171e) on p. 230 vs. (177) on p. 232).

Fifth, despite all this additional machinery, there are attested constructions that – as far as we see – cannot be handled in the approach of Zimmermann 2002. We introduce one such construction below.

3 Inverse Linking Distance Distributivity Construction

There is a construction problematic for previous analyses of DD, bearing certain resemblance to the inverse linking construction discussed in May 1985: 68ff. and Heim and Kratzer 1998: § 8.6, among others. In this construction – exemplified with the Polish sentence (3) (whose schematic syntactic structure is given in (4)) and the corresponding German sentence (5) – the distributive key is syntactically embedded within the distributive share:

(3) Przybyło po 3 przedstawicieli 25 krajów. (Polish)
arrive$_{\text{PAST}}$ DISTR 3 representatives 25$_{\text{GEN}}$ countries$_{\text{GEN}}$
'3 representatives arrived from each of 25 countries.'

(4) Przybyło [po [3 [przedstawicieli [25 krajów]]]].

(5) Jeweils 3 Abgeordnete aus 25 Ländern trafen ein. (German)
DISTR 3 representatives from 25 countries arrived
'3 representatives arrived from each of 25 countries.'
(Malte Zimmermann, p.c.)

The structure given in (4) is not controversial. The Polish DE *po* is analysed as – or simply assumed to be – a preposition (Łojasiewicz 1979, Franks 1995) which combines with the following nominal phrase.[4] Numerals are

[4] While there are reasons to postulate more than one DE *po* in Polish, they are all best analysed as heads (Przepiórkowski 2006, 2010, 2013, Przepiórkowski and Patejuk 2013),

also analysed as heads of numeral phrases in Polish on the basis of substitution tests and case assignment (Saloni and Świdziński 1998, Przepiórkowski 1999; but see also Franks 1995). In any case, whether the numeral phrase *3 przedstawicieli...* 'three representatives...' is taken to be headed by the numeral or by the noun, *25 krajów* '25 countries' is an argument of *przedstawicieli* 'representatives', so – at least at the surface – it must be contained in the maximal projection of this noun.[5] Hence, the DK *25 krajów* '25 countries' is contained within the DS *3 przedstawicieli 25 krajów* '3 representatives of 25 countries'.

Note that although (3) is a constructed example, analogous attested examples may easily be found in the National Corpus of Polish (NKJP; Przepiórkowski et al. 2012; http://nkjp.pl/) and in the Internet, e.g. (constraining our search to the same relational noun):[6]

(6) ...proponował po dwóch przedstawicieli miasta
proposed$_{M1}$ DISTR two$_{ACC.M1}$ representatives$_{ACC.M1}$ city$_{GEN.N}$
i ComArchu...
and ComArch$_{GEN.M3}$
'...he proposed two representatives for each of the city and ComArch.' (NKJP)

(7) W skład jury wchodzi po 2
into make-up$_{ACC}$ jury$_{GEN}$ enters DISTR two$_{ACC.M1}$
przedstawicieli organizatorów konkursu.
representatives$_{ACC.M1}$ organisers$_{GEN.M1}$ competition$_{GEN.M3}$
'2 representatives of each of the organisers of the competition belong to / constitute the jury.'
(http://zporuszcza.polaniec.pl/index_pliki/bezpieczna_skola.pdf)

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so treating them all as prepositions is a reasonable first approximation. Note that they differ from the prefix *po-* (Bogusławski 1993, http://pinon.sdf-eu.org/covers/dpp.html), which has a related but different distributive meaning.

[5] Note that this is an island, presumably also for covert movement:

(i) *Czego przybyło po 3 przedstawicieli?
what$_{GEN}$ arrive$_{PAST}$ DISTR 3 representatives

[6] In the glosses, M1 stands for the human-masculine gender and M3 – for inanimate-masculine, assuming the 5 Polish genders proposed in Mańczak 1956. Other morpho-syntactic symbols follow the Leipzig Glossing Rules.

In the examples above, the DK is an argument of the relational noun *przedstawiciel* 'representative', which heads the DS. Examples of DK adjuncts to heads of DSs are also easy to find, but they are not discussed here, as they do not pose a particular problem for Zimmermann's analysis.

Let us attempt to analyse such constructions. The cross-linguistic denotation of DEs proposed by Zimmermann 2002: 122 is given below:

(8) $[\![\text{DE}]\!] = \lambda P.\forall z[(z \in Z_i) \rightarrow \exists x[P(x) \wedge R_j(z,x)]]$

In this representation, P stands for the property expressed by the DS. For example, in *The boys have two apples each*, P would be the property of being a set of two apples; let us schematically represent this property as $\lambda x.2apples(x)$. Given the representation of *each* in (8), *two apples each* receive the following representation (via functional application):

(9) $[\![\textit{two apples each}]\!] = \forall z[(z \in Z_i) \rightarrow \exists x[2apples(x) \wedge R_j(z,x)]]$

Z_i and R_j are variables which are coindexed with, respectively, the DK (*the boys*) and the relation between the DK and the DS (*have*). Via the "Index-Triggered λ-Abstraction" (Zimmermann 2002: 217), when the phrase *two apples each* with the representation in (9) is a constituent-tree sister of a node with index j, expressing a 2-place relation such as $\lambda z\lambda x.have(z,x)$, (9) can be transformed to (10) below and then be applied to the *have*-relation to render (11) for the verbal phrase (VP) *have two apples each*.

(10) $[\![\textit{two apples each}]\!] = \lambda R_j.\forall z[(z \in Z_i) \rightarrow \exists x[2apples(x) \wedge R_j(z,x)]]$

(11) $[\![\textit{have two apples each}]\!] = \forall z[(z \in Z_i) \rightarrow \exists x[2apples(x) \wedge have(z,x)]]$

Similarly, when the VP is a sister to *the boys* indexed with i, λ-abstraction is licensed again (see (12)) resulting in a function that can be applied to the meaning of *the boys*, giving the meaning of the sentence in (13).

(12) $[\![\textit{have two apples each}]\!] =$
$\lambda Z_i.\forall z[(z \in Z_i) \rightarrow \exists x[2apples(x) \wedge have(z,x)]]$

(13) $[\![\textit{the boys have two apples each}]\!] =$
$\forall z[(z \in [\![\textit{the boys}]\!]) \rightarrow \exists x[2apples(x) \wedge have(z,x)]]$

Returning to (3), its analogous desired representation is given in (14):[7]

[7] We ignore here the event variable introduced by the verb and bound via existential closure at the end of the derivation, but see below.

(14) $[\![$*przybyło po 3 przedstawicieli 25 krajów*$]\!] =$
$\forall z[(z \in [\![$*25 countries*$]\!]) \rightarrow \exists x[$*3representatives*$(x,z) \wedge$ *arrived*$(x)]]$

How can it be derived, assuming the representation of the DE *po* as in (8)? For the sake of the argument, let us give as much leeway to Zimmermann's approach as possible and assume that any kind of LF-movement is allowed, even in violation of island constraints.

The DE must first combine with its sister – either the DS or a trace resulting from movement. But since traces are of the semantic type <*e*>, and DE expects a property of type <*e*,*t*>, no movement of the whole DS is possible.[8] On the other hand, we have to assume the LF-movement of *25 krajów* '25 countries'; otherwise, if the whole *3 przedstawicieli 25 krajów* '3 representatives of 25 countries' is consumed as *P*, there would be no DK to subsequently provide the meaning of Z_i. So the only way to proceed with the analysis is to assume the following schematic structure at LF:

(15) [25 krajów]$_i$ [przybyło [po 3 przedstawicieli t_i]]

The DE *po* expects a property, so let us assume the representation of the argument of *po* as in (16) and the result of its combination with the representation of *po* given in (8) – as in (17):

(16) $[\![$*3 przedstawicieli* $t_i]\!] = \lambda x.$*3representatives*(x, z_i)

(17) $[\![$*po 3 przedstawicieli* $t_i]\!] =$
$\forall z[(z \in Z_i) \rightarrow \exists x[$*3representatives*$(x, z_i) \wedge R_j(z,x)]]$

This representation is already getting incoherent, as it now involves two variables coindexed with *25 krajów* 'countries' – z_i of type <*e*> and Z_i of type <*e*,*t*>. Obviously, instead of the variable z_i, the second argument of *3representatives* should be the variable z bound by the universal quantifier. Hence, the existential closure over z_i in (16) would not help here either. Even if this problem could somehow be solved, there is no binary relation that could provide the meaning of the binary R_j – *przybyło* 'arrived' is a unary predicate.[9]

[8] Also, the "Index-Triggered λ-Abstraction" is not applicable in this configuration.

[9] Zimmermann 2002: 226, fn. 67, considers the possibility of a *family* of denotations for DE, with R_j of different arities greater or equal to 2. Perhaps this idea could be extended even further, to R_j of arity 1, but this would not solve the problem of the incoherent

Since there is no constituent in the representation of (3) that expresses a binary relation needed to provide the denotation of R_j, let us attempt to analyse this sentence in a way analogous to the German (18), which also involves a unary predicate (the idiomatic *keep watch*).

(18) Jeweils zwei Jungen standen Wache. (German)
DISTR two boys_{NOM} kept guard
'Two boys kept watch at a time.' (Zimmermann 2002: 249)

Here, the distribution is over events; the target denotation can be paraphrased as "for all elements z of a contextually salient set (of events) Z_i, there is a set of two boys x, and an event e, such that the elements of x kept watch in e, and event e is related to event z by a temporal, causal, subpart, or other contextual relation R" (Zimmermann 2002: 261):

(19) $[\![\textit{jeweils zwei Jungen standen Wache}]\!] =$
$\forall z[(z \in Z_i) \rightarrow \exists x[2boys(x) \wedge \exists e[kept\_watch(x,e) \wedge R(e,z)]]]$

In order to derive this representation, Zimmermann 2002: 259 assumes the standard representation of *jeweils* in (8), which gives rise to the following representation of *jeweils zwei Jungen*:

(20) $[\![\textit{jeweils zwei Jungen}]\!] = \forall z[(z \in Z_i) \rightarrow \exists x[2boys(x) \wedge R_j(z,x)]]]$

The meaning of the verbal component t_1 *standen Wache*, with t_1 representing the trace of the subject *jeweils zwei Jungen*, is less obvious (here, after applying λ-abstractions):

(21) $[\![t_1 \textit{ standen Wache}]\!] = \lambda x_1 \lambda e_i . \exists e[kept\_watch(x_1,e) \wedge R(e,e_i)]$

The variable x_1 in (21) represents the subject of the predicate, while R represents a contextually given relation between the event e predicated by the verb and an event e_i in the preceding discourse (Zimmermann 2002: 260). This way the denotation of *standen Wache* 'stood guard' is a 2-place predicate, as expected. With this representation of the verbal predicate, the result of λ-abstraction of R_j in (20) applied to (21) is (19) above.

How can this analysis be carried over to (3)? First of all, let us assume the representation of *przybyło* 'arrived' analogous to that in (21):

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representation in (17). Also, the analysis proposed below does not have to assume a family of representations of the DE *po*.

(22) $[\![t_1\ przybyło]\!] = \lambda e_i \lambda x_1.\exists e[arrived(x_1,e) \wedge R(e,e_i)]$

Assuming λ-abstraction over R_j in (17) above and subsequent application of the resulting function to the denotation in (22), the denotation in (23) below results. Combining this representation with that of *25 krajów* '25 countries', we get (24).

(23) $[\![przybyło\ po\ 3\ przedstawicieli\ t_i]\!] =$
$\forall z[(z \in Z_i) \rightarrow \exists x[3representatives(x,z_i) \wedge \exists e[arrived(x,e) \wedge R(e,z)]]]$

(24) $[\![przybyło\ po\ 3\ przedstawicieli\ 25\ krajów]\!] =$
$\forall z[(z \in [\![25\ krajów]\!]) \rightarrow$
$\exists x[3representatives(x,z_i) \wedge \exists e[arrived(x,e) \wedge R(e,z)]]]$

This representation is close to the correct one but – unfortunately – it again contains the free variable z_i which should really be bound by the universal quantifier $\forall z$.

Note that the target representation in (14) *could* be derived from the DE denotation in (8), but such a derivation would violate Zimmermann's basic assumptions about constituency and surface compositionality: the DE *po* would first have to combine with *przybyło* 'arrived' in (25) rendering the denotation in (26), then with *3 przedstawicieli* '3 representatives' treated as a binary relation $\lambda z \lambda x.3representatives(x,z)$, resulting in (27), and then with *25 krajów* '25 countries', resulting in (28):

(25) $[\![przybyło]\!] = \lambda x.arrived(x)$

(26) $[\![przybyło\ po]\!] = \forall z[(z \in Z_i) \rightarrow \exists x[arrived(x)] \wedge R_j(x,z)]$

(27) $[\![przybyło\ po\ trzech\ przedstawicieli]\!] =$
$\forall z[(z \in Z_i) \rightarrow \exists x[arrived(x) \wedge 3representatives(x,z)]]$

(28) $[\![przybyło\ po\ trzech\ przedstawicieli\ 25\ krajów]\!] =$
$\forall z[(z \in [\![25\ countries]\!]) \rightarrow \exists x[arrived(x) \wedge 3representatives(x,z)]]$

In summary, whether treating (3) as an instance of distribution over entities (25 countries) or over events (arrivals), we do not see a way to derive an acceptable meaning of this sentence, given the approach of Zimmermann 2002. This, combined with the reservations expressed in § 2, calls for a new approach to distance distributivity in Polish; such an approach is sketched below.

4 An Outline of an Alternative Account

The main idea of an alternative account, more fully described in Przepiórkowski 2014a, from which this section draws heavily, is this: the semantic impact of *po* activates only once the distributive share combines semantically with the verb and creates a property. For example, in case of (3), the meaning of *przybyło 3 przedstawicieli*, 'λY. 3 representatives of Y arrived', is derived first. Then, the meaning of *po* combines with this property, let us call it S, holding of some set Y, and produces a new property, which is just like S but holds of each element of Y individually: 'λY. for each element y of Y, 3 representatives of y arrived'. Finally, this new property combines with the distributive key *25 krajów* '25 countries', resulting in the meaning: 'for each of 25 countries, 3 representatives arrived'.

This idea relies on the possibility to combine the meaning of *po* with the property 'λY. 3 representatives of Y arrived' expressed by *przybyło 3 przedstawicieli*, rather than with the meaning of the syntactic sister of *po*. It would be difficult to implement this idea in a framework that understands compositionality narrowly, as in these two recent formulations:

- *The meaning of a complex expression functionally depends on the meanings of its immediate parts and the way in which they are combined.* (Zimmermann 2012: 82)
- *The meaning of a complex expression is determined by its immediate structure and the meanings of its immediate constituents.* (Szabó 2012: 79)

This is the usual understanding of compositionality – unquestioned in transformational approaches – but it is not the only one. In fact, as discussed in detail in Janssen 2012 and Szabó 2012, the provenance of this – originally massively ambiguous – principle is murky (it should probably *not* be attributed to Frege, but rather to his student, Carnap 1947), there are no strong fundamental – as opposed to methodological – arguments for adopting it, and the reasons for its widespread use are mostly technical.

As noted already in 1987 (see the reprint, Halvorsen 1995: 295), compositionality should be replaced in constraint-based theories by *systematicity*, a method of automatic derivation of utterance interpretations from the lexical information and any rules of the interpretation scheme.[10] The

[10] This emphasis on the meanings of utterances rather than the meanings of arbitrary

alternative analysis of DD in Polish is couched in just such a constraint-based theory, namely, Lexical Functional Grammar (LFG; Bresnan 2001, Dalrymple 2001), coupled with a resource-based approach to meaning composition, namely, Glue Semantics (Dalrymple 1999, 2001). The latter explicitly adopts this weak notion of compositionality, *where the meaning of a sentence depends on the meanings of its words and the way these are combined, but where syntactic structure and lexical semantics may not fully specify either* (Crouch and van Genabith 1999: 122).

In traditional approaches to compositionality (e.g., Heim and Kratzer 1998), meanings combine when they are expressed by siblings in a constituency tree. By contrast, in LFG + Glue, meanings combine based on f(unctional)-structures, rather than on c(onstituent)-structures, and meaning representations are paired with glue formulae specifying how these meanings combine with which other meanings. Any pair consisting of a meaning representation and a glue formula is called a *meaning constructor*.

For example, the glue part of the meaning constructor for various forms of *yawn* is:

(29) $(\uparrow \text{SUBJ})_\sigma \multimap \uparrow_\sigma$

As usual in LFG, the up arrow $\uparrow$ in a lexical entry denotes the f-structure of the word, $(\uparrow \text{SUBJ})$ denotes the f-structure of the subject of this word, and σ is a function from f-structures to s(emantic)-structures. In effect, (29) says that, by consuming the s-structure corresponding to the subject of *yawn*, we may produce the s-structure corresponding to *yawn* and, hence, to the whole clause headed by *yawn* (in LFG heads normally share their f-structure with their projections).

This mode of composition remains true regardless of specific tree configurations. For example, when *yawn* is a complement of a control verb, its covert subject is never realised in the c(onstituent)-structure, according to standard LFG analyses, but it is still present in its f-structure, as the value of the SUBJ attribute, so (29) is still relevant.

The other part of the meaning constructor is a formula in any language that allows application and abstraction, e.g., the language of the first-order predicate logic with lambda calculus. For example, the meaning of *David*

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syntactic components is strongly related to the principle of *contextuality*, a postulate that does deserve to be called *Frege's principle*; see Janssen 2012 for discussion.

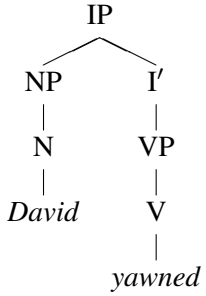
can be defined as a logical constant, *David*, and the meaning of *yawned* can be defined as usual, as $\lambda X.yawn(X)$ (ignoring event variables, semantic roles, tense and aspect, etc.). In complete meaning constructors, the meaning part is separated from the glue part by the uninterpreted colon character (:), so the complete meaning constructors for *David* and *yawned* are as in the second lines of the following lexical entries:

(30) *David* N $(\uparrow \text{PRED}) = \text{`DAVID'}$
$David : \uparrow_\sigma$

(31) *yawned* V $(\uparrow \text{PRED}) = \text{`YAWN<SUBJ>'}$
$\lambda X.yawn(X) : (\uparrow \text{SUBJ})_\sigma \multimap \uparrow_\sigma$

According to these lexical entries and standard LFG constituency rules, *David yawned* receives the c-structure displayed in (32) and the f-structure in (33); moreover, given this f-structure, meaning constructors are instantiated as in (34):

(32)



(33)
$$\boxed{0}\begin{bmatrix} \text{PRED} & \text{`YAWN}\langle\boxed{1}\rangle\text{'} \\ \text{SUBJ} & \boxed{1}\begin{bmatrix}\text{PRED} & \text{`DAVID'}\end{bmatrix}\end{bmatrix}$$

(34) **[David]** $David : \boxed{1}_\sigma$
[yawned] $\lambda X.yawn(X) : \boxed{1}_\sigma \multimap \boxed{0}_\sigma$

Now, using one of the proof rules of Glue Semantics, namely, the Implication Elimination rule in (35), and performing the usual β-reduction, the meaning of *David yawned* may be derived from the meaning constructors in (34) as shown in (36):

(35)
$$\frac{a : A \qquad f : A \multimap B}{f(a) : B} \multimap_{\mathscr{E}}$$

(36)
$$\frac{David : \boxed{1}_\sigma \qquad \lambda X.yawn(X) : \boxed{1}_\sigma \multimap \boxed{0}_\sigma}{yawn(David) : \boxed{0}_\sigma} \multimap_{\mathscr{E}}$$

Since both meaning resources introduced by lexical items, $\boxed{1}_\sigma$ and $\boxed{1}_\sigma \multimap \boxed{0}_\sigma$, were consumed in this proof, and the only meaning resource produced, $\boxed{0}_\sigma$, corresponds to the f-structure of the whole sentence, this is a valid proof that the meaning side of the whole sentence is $yawn(David)$.

Obviously, we cannot do justice to Glue Semantics within the confines of this paper; the above is only meant to make the analysis below more accessible to motivated readers not familiar with this approach. The best introduction to Glue Semantics may still be found in the classical LFG textbook of Dalrymple 2001, on which the above exposition is based.

Let us now return to the problematic distance distributivity construction exemplified by (3), repeated below:

(3) Przybyło po 3 przedstawicieli 25 krajów.
arrive$_{\text{PAST}}$ DISTR 3 representatives 25$_{\text{GEN}}$ countries$_{\text{GEN}}$
'3 representatives arrived from each of 25 countries.'

The lexical entry for *przybyło* 'arrived' matches that of *yawned* given in (31) above (note that we ignore the event variable again, solely for reasons of simplicity):

(37) *przybyło* V $(\uparrow \text{PRED}) = \text{'ARRIVE<SUBJ>'}$
$\lambda X.arrive(X) : (\uparrow \text{SUBJ})_\sigma \multimap \uparrow_\sigma$

The meaning constructors of common nouns are a little less obvious:

(38) *krajów* N $(\uparrow \text{PRED}) = \text{'COUNTRIES'}$
$\lambda X.country^s(X) \wedge |X| > 1 : (\uparrow_\sigma \text{VAR}) \multimap (\uparrow_\sigma \text{RESTR})$

First, we follow Dotlačil 2012 and earlier work on treating type e objects as sets, and properties – as sets of such sets. For example, $country^s$ is the property of being a non-empty set of countries – either a singleton or a set of higher cardinality (the superscript s indicates the possible plural) – and $\lambda X.|X| > 1 \wedge country^s(X)$ is the property of being a set of at least two countries. On this view, the standard inclusion relation $\subseteq$ is defined on type e objects. Second, the glue side shows that semantic structures may have some internal structure: s-structures of common nouns, which are of type $\langle e,t \rangle$, have the attributes VAR and RESTR, representing a variable (of type e) and a restriction on that variable (of type t); cf. Dalrymple 2001: 250–253.

Entries of relational nouns are just like those of common nouns, but they add a specification of an internal argument:

(39) *przedstawicieli* N $(\uparrow \text{PRED}) = \text{`REPRESENTATIVES<OBJ>'}$
$\lambda Y.\lambda X\, representative^{s}(X,Y) \wedge |X| > 1 :$
$(\uparrow \text{OBJ})_{\sigma} \multimap [(\uparrow_{\sigma} \text{VAR}) \multimap (\uparrow_{\sigma} \text{RESTR})]$

The meaning constructor of (39) differs from that of (38) and other non-relational nouns in the additional requirement of the semantic resource corresponding to the argument of the noun.

Further, simplifying somewhat, we treat cardinals as existential quantifiers:

(40) *3* Num $(\uparrow \text{SPEC}) = 3$
$\lambda R.\lambda S.exists(Y, |Y| = 3 \wedge R(Y), S(Y)) :$
$[(\uparrow_{\sigma} \text{VAR}) \multimap (\uparrow_{\sigma} \text{RESTR})] \multimap [\forall H.[\uparrow_{\sigma} \multimap H] \multimap H]$

(41) *25* Num $(\uparrow \text{SPEC}) = 25$
$\lambda R.\lambda S.exists(Y, |Y| = 25 \wedge R(Y), S(Y)) :$
$[(\uparrow_{\sigma} \text{VAR}) \multimap (\uparrow_{\sigma} \text{RESTR})] \multimap [\forall H.[\uparrow_{\sigma} \multimap H] \multimap H]$

As common in LFG and Glue Semantics, generalised quantifiers are represented here as *pair quantifiers*, that is, as relations between an individual and two propositions involving that individual, so that *Someone yawned* has the basic representation $exists(X, person(X), yawn(X))$ (Dalrymple 2001: 227). In our setup, cardinality is additionally specified, so – for example – *Two people yawned* will have the following representation: $exists(X, person^{s}(X) \wedge |X| = 2, yawn(X))$.

Finally, we assume the following lexical entry of *po*:

(42) *po* P $(\uparrow \text{PRED}) = \text{`PO<OBJ>'}$
$(\uparrow \text{OBJ})_{\sigma} = \uparrow_{\sigma}$
$\lambda S.\lambda Z.all(X, |X| = 1 \wedge X \subset Z, S(X)) :$
$\forall G, H.\ [G \multimap H] \multimap [G \multimap H]$

Observe that *po* is analysed as a preposition here (but see fn. 4). The import of the second line, $(\uparrow \text{OBJ})_{\sigma} = \uparrow_{\sigma}$, will be explained below. The third line – the meaning part of the meaning constructor – says that *po* takes a property S and returns a property that holds of Z if and only if S holds of all singleton (proper) subsets of Z. Finally, the glue part in the fourth line says that *po*

is an identity function on semantic resources corresponding to properties: it consumes any resource $[G \multimap H]$ in order to produce the same resource. Since G and H may be any semantic resources (of appropriate types), this analysis is much too permissive as it stands – it is appropriately constrained in Przepiórkowski 2014b.

We do not present here syntactic rules which serve to build the constituency structure of the running example, as they are trivial and of secondary importance to the current analysis. Crucially, we assume that these rules – together with the lexical entries above – lead to the following functional structure for the complete sentence in (3):

(43)
$$\boxed{0}\begin{bmatrix} \text{PRED} & \text{`ARRIVED}\langle\boxed{1}\rangle\text{'} \\ \text{SUBJ} & \boxed{1}\begin{bmatrix} \text{PRED} & \text{`PO}\langle\boxed{2}\rangle\text{'} \\ \text{OBJ} & \boxed{2}\begin{bmatrix} \text{SPEC} & \text{`3'} \\ \text{PRED} & \text{`REPRESENTATIVE}\langle\boxed{3}\rangle\text{'} \\ \text{OBJ} & \boxed{3}\begin{bmatrix} \text{SPEC} & \text{`25'} \\ \text{PRED} & \text{`COUNTRY'} \end{bmatrix} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

While there are syntactic reasons to assume that numerals take the following NPs as their arguments, we simplify here by treating the numeral and the following noun as co-heads. Hence, both the lexical entry for *krajów* in (38) and the lexical entry for *25* in (41) contribute to the innermost feature structure in (43), marked with the label $\boxed{3}$. In other words, the $\uparrow$ variable in these lexical entries instantiates to $\boxed{3}$, so the meaning constructors instantiate, respectively, to:

(44) **[countries]**
$\lambda X.country^s(X) \wedge |X| > 1 : (\boxed{3}_\sigma \text{VAR}) \multimap (\boxed{3}_\sigma \text{RESTR})$

(45) **[25]**
$\lambda R.\lambda S.exists(X, |X| = 25 \wedge R(X), S(X)) :$
$\big[(\boxed{3}_\sigma \text{VAR}) \multimap (\boxed{3}_\sigma \text{RESTR})\big] \multimap \big[\forall H.[\boxed{3}_\sigma \multimap H] \multimap H\big]$

Using the Implication Elimination rule in (35), and performing the usual β-reduction, these meanings combine to:[11]

[11] In (35), substitute "$(\boxed{3}_\sigma \text{VAR}) \multimap (\boxed{3}_\sigma \text{RESTR})$" for A, "$\forall H.[\boxed{3}_\sigma \multimap H] \multimap H$" for B, "$\lambda X.country^s(X) \wedge |X| > 1$" for a and "$\lambda R.\lambda S.exists(X, |X| = 25 \wedge R(X), S(X))$" for f.

(46) **[25-countries]**
$\lambda S.exists(X, |X| = 25 \wedge country^{s}(X), S(X)) : \forall H.[\boxed{3}_{\sigma} \multimap H] \multimap H$

Similarly, lexical entries (39) (for *przedstawicieli*) and (40) (for *3*) contribute to the construction of f-structure $\boxed{2}$, so $\uparrow$ in those entries instantiates to $\boxed{2}$ and, hence, $(\uparrow \text{OBJ})$ instantiates to $\boxed{3}$:

(47) **[representatives]**
$\lambda Y.\lambda X.representative^{s}(X,Y) \wedge |X| > 1 :$
$\boxed{3}_{\sigma} \multimap [(\boxed{2}_{\sigma}\text{VAR}) \multimap (\boxed{2}_{\sigma}\text{RESTR})]$

(48) **[3]**
$\lambda R.\lambda S.exists(X, |X| = 3 \wedge R(X), S(X)) :$
$[(\boxed{2}_{\sigma}\text{VAR}) \multimap (\boxed{2}_{\sigma}\text{RESTR})] \multimap [\forall H.[\boxed{2}_{\sigma} \multimap H] \multimap H]$

(49) **[3-representatives]**
$\lambda Y.\lambda S.exists(X, |X| = 3 \wedge representative^{s}(X,Y), S(X)) :$
$\forall H.\ \boxed{3}_{\sigma} \multimap [[\boxed{2}_{\sigma} \multimap H] \multimap H]$

In fact, in order to derive **[3-representatives]** from **[3]** and **[representatives]**, another standard proof rule is needed, Implication Introduction (Dalrymple 2001: 236, Asudeh 2012: 79), which we will not cite here for lack of space. Instead we note that the proof captures the intuition behind the function composition in Categorial Grammar (cf., e.g., Steedman 2000: 40), where functions X/Y and Y/Z may compose into X/Z.

Given the f-structure (43), the meaning constructor of *przybyło* in (37) instantiates to **[arrived]**, as $\uparrow$ instantiates to $\boxed{0}$ and, hence, $(\uparrow \text{SUBJ})$ – to $\boxed{1}$:

(50) **[arrived]**
$\lambda X.arrived(X) : \boxed{1}_{\sigma} \multimap \boxed{0}_{\sigma}$

Finally, the meaning constructor of *po* in (42) contains no $\uparrow$ symbols, only variables G and H matching any (appropriately typed) resource, but there is another line in this lexical entry, $(\uparrow \text{OBJ})_{\sigma} = \uparrow_{\sigma}$, which – given (43) – instantiates to $\boxed{2}_{\sigma} = \boxed{1}_{\sigma}$. The intuition behind this meaning constructor and this constraint is that *po* makes no semantic impact where it occurs – it equates its semantic resource $\boxed{1}_{\sigma}$ with that of its argument $\boxed{2}_{\sigma}$ – but it contributes the distributive meaning constructor which activates elsewhere in the semantic derivation.

Given that $\boxed{2}_\sigma = \boxed{1}_\sigma$, and substituting $\boxed{0}_\sigma$ for H in the meaning constructor **[3-representatives]** (49), this constructor may be combined with **[arrived]** (50) (again, via a few proof steps, including Implication Introduction), rendering:

(51) **[arrived-3-representatives]**
$\lambda Y.exists(X, |X| = 3 \wedge representative^s(X,Y), arrived(X)) : \boxed{3}_\sigma \multimap \boxed{0}_\sigma$

After substituting G and H with, respectively, $\boxed{3}_\sigma$ and $\boxed{0}_\sigma$ in the meaning constructor for *po* in (42), **[arrived-3-representatives]** combines with this meaning constructor directly, resulting in:

(52) **[distr-arrived-3-representatives]**
$\lambda Z.all(Y, |Y| = 1 \wedge Y \subset Z,$
$\quad exists(X, |X| = 3 \wedge representative^s(X,Y), arrived(X))) : \boxed{3}_\sigma \multimap \boxed{0}_\sigma$

Finally, substituting $\boxed{0}_\sigma$ for H in the meaning constructor for the quantifier phrase *25 krajów*, given in (46), it combines directly with the above meaning constructor (52), rendering the intended meaning of the whole functional structure $\boxed{0}$:

(53) **[25-countries-distr-arrived-3-representatives]**
$exists(Z, |Z| = 25 \wedge country^s(Z),$
$\quad all(Y, |Y| = 1 \wedge Y \subset Z,$
$\quad\quad exists(X, |X| = 3 \wedge representative^s(X,Y), arrived(X)))) : \boxed{0}_\sigma$

5 Conclusion

One of the first influential analyses of distance distributivity, Choe 1987, is not compositional. Further work – of which Zimmermann 2002 is a premiere example – tried to provide compositional analyses of the phenomenon at the syntax-semantics interface. While it remains the most comprehensive analysis of DD of the kind also observed in Slavic languages, it is not without problems and limitations, discussed in § 2 and § 3. The alternative analysis, outlined in § 4, is compositional in a rather weak sense, but it is systematic: the meaning of an utterance is derived from the meanings of lexical items and the way they combine. Even if not all technical details of the presented analysis are transparent to readers not previously exposed to LFG and Glue Semantics, it should be clear that the advantage of this relaxed approach to compositionality is a much simpler

syntax: no *ad hoc* (covert movement, etc.) rules are needed to account for the semantic complexity. Instead, the complexity resides exactly where it should: in the lexical entries of semantically complex items.

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