Reducing Homogeneity to Distributivity*

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Abstract. This paper examines the semantics of homogeneity, being specifically concerned with the question whether or not homogeneity can be reduced to distributivity. Recent influential accounts of homogeneity in Križ 2015, 2019 have argued that such a reduction is not possible, as there are collective predicates that show homogeneity. We argue that in fact the empirical landscape is more complicated: while true that some collective predicates show homogeneity, not all collective predicates have this property. Collective activities and accomplishments show homogeneity, whereas collective states and achievements do not. Interestingly, collective accomplishments and activities have been analyzed as being able to host a D operator in their structure, while this is not possible for collective states and achievements (Brisson 2003). Therefore, once we control for the aktionsart of a collective predicate, it emerges that the collective predicates that allow homogeneity are exactly those that allow distributivity. We therefore conclude that we can reduce homogeneity to distributivity.

Keywords: Homogeneity · Distributivity · Collective Predicates · Aktionsart.

1 Introduction

Definite plurals require the verbal predicate to hold either of all or none of the parts of the plural individual they denote (Fodor 1970, Schwarzschild 1994, Križ 2015 a.o.):

(1) a. The knights died in battle.
    b. The knights did not die in battle.

Assume a model where there are 5 knights. (1-a) is True iff **all** of the five knights died in battle. (1-b) is true iff **none** of the five knights died in battle. In a mixed situation where three knights did in battle and two knights did not,

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the sentences have been claimed to be neither true not false; rather they are undefined (modulo non-maximality, which we leave aside in the present paper). This property of definite plurals is called homogeneity.

The rest of this paper is organised as follows: Section 2 briefly reviews previous approaches to homogeneity. Section 3 attempts to probe the empirical landscape of which collective predicates license homogeneity and which do not. Section 4 connects the results of section 3 to work in Brisson 2003, and section 5 uses the tools developed in Brisson's work to develop an analysis where homogeneity arises via distributivity. Section 6 examines the extent to which our account captures various cases of homogeneity. Section 7 concludes.

2 Accounts of homogeneity

2.1 Homogeneity tied to distributivity

One approach to homogeneity takes it to be associated in some way with distributive predicates (Schwarzschild 1994, Gajewski 2005) (see also the discussion in chapter 1 of Križ 2015 for more details). Gajewski 2005 for instance models homogeneity directly as an excluded middle presupposition in the meaning of the D(istributivity) operator, Link 1983[1]:

(2) $$||D|| = \lambda P.\lambda x : (\forall y \leq_\alpha x : P(y)) \vee (\forall y \leq_\alpha x : \neg P(y)).\forall y[y \leq_\alpha x \rightarrow P(y)]$$

He starts from the assumption that distributive predicates are primitively defined just for atoms and that in order to apply to pluralities, a D operator (Link 1983) needs to apply to them. So, in (1), the function denoted by 'die' cannot apply directly to the plural individual denoted by 'the knights' (assuming that 'the knights' denotes the maximal plural individual that is a knight in the model). Instead, 'die' combines with the D operator, yielding [D [die]]', which then combines with 'the knights'. Thus, the LF of (1) is as in (3):

(3) [The knights [D [died-in-battle]]

Here is how Gajewski's operator gives us homogeneity: In models where all atomic knights either died or did not die, the presupposition of the D operator is satisfied. Thus, (1-a) is predicted to be true iff all atomic knights died, and false iff all atomic knights did not die.

However, imagine model with the following extensions

(4) a. $||knight|| = \{a, b\}$
b. $||knights|| = {}^*||knight|| = \{a, b, a \oplus b\}$
c. $||the\ knights|| = a \oplus b$
d. $||king]|| = \{c\}$

[1] Throughout the paper $\oplus$ represents the summation operation on the domain of individuals, D_e. $\leq$ represents the part-of relation on individuals defined in the usual way. $\leq_\alpha$ represents the atomic-part relation. * is the star operator which takes a predicate and closes it under $\oplus$. See Link 1983 for further details.

e. $||die\ in\ battle]|| = \{a, c\}$

The LF in (3) will have the following truth conditions (based on (2)):

(5) $\forall y[y \leq_{\alpha} a \oplus b \rightarrow died - in - battle(y)]$

It will also have the following presupposition:

(6) $(\forall y \leq_{\alpha} a \oplus b : died - in - battle(y)) \vee (\forall y \leq_{\alpha} a \oplus b : \neg died - in - battle(y))$

In this case knight a is in $||die\ in\ battle||$, but b is not. Therefore, the presupposition in (6) cannot be satisfied and presupposition failure arises, which we can think of as undefinedness (see e.g. Heim 1983).

2.2 Homogeneity as an irreducible property

Another approach is that homogeneity is not a reducible property of predicates (Križ 2015, 2019). Importantly, it cannot be reduced to distributivity, because there are collective predicates that show homogeneity[2]. Rather, homogeneity has to be taken as 'a fundamental property of lexical predicates'[3] (Križ 2019) (i.e. non-derived elements that are listed in the lexicon are born homogenous.).

Križ's main argument that homogeneity is not reducible to distributivy stems from the existence of collective predicates that show homogeneity:

(7) a. The students performed *Hamlet*.
b. The students did not perform *Hamlet*

The sentences in (7) seem to require that either all, (7-a), or none, (7-b), of the students participated in a performance of *Hamlet*. They also seem undefined in a mixed situation where only half of the students for instance performed/ did not perform *Hamlet*. But 'perform *Hamlet*' is a collective activity. Thus, homogeneity is found beyond distributive predicates. We will consider this argument more deeply in sections 4 and 5, where we will argue that distributivity is in fact involved in predicates like 'perform *Hamlet*'.

Since homogeneity cannot be identified with distributivity, one needs to state what it means for a predicate to be homogeneous in a way that captures both distributive homogeneous predicates and collective homogeneous predicates. Križ 2019 suggests the following:

[2] Furthermore, Križ argues that the gap associated with homogeneity cannot be reduced to presupposition projection. Since, this is point is orthogonal to the concerns of our paper, we do not go into the details.

[3] This formulation is somewhat ambiguous. It could be taken to mean either (i) that elements of the lexicon need to be specified for their homogeneity, i.e. marked [+/-homogeneous]), or (ii) that every element of the lexicon is homogeneous by default. In light of the fact that Križ views non-homogeneous collective predicates like 'numerous' as exceptions to the idea that homogeneity is a property of lexical predicates, we adopt the second interpretation. Under the first interpretation, one could take predicates like 'numerous' to be simply specified as [-homogeneous], and thus unexceptional.

(8) **Homogeneity Generalization:** A homogeneous predicate P that is not true of a plurality *a* is undefined of *a* if it is true of some plurality *b* that overlaps (i.e. has parts in common)[4] with *a*.

This distinguishes the following cases of homogeneity[5]:

(9) P is not true of *a* and it is true of *b* and ...
 a. *b* is properly contained in *a* (Downward Homogeneity)
 b. *a* is properly contained in *b* (Upward Homogeneity)
 c. *a* and *b* overlap, but neither contains the other (Sideways Homogeneity)

Applying the generalization in (8) to various predicates, Križ identifies two exceptions to the claim that homogeneity is a lexical property:

First, there are (lexical) collective predicates that resist homogeneity. These tend to be measure expressions, like 'be numerous' or 'be heavy'.

(10) The knights were heavy/ numerous

(10) can be true, and not undefined, in a situation where the various subgroups of knights are not heavy, but the plurality of all the knights is heavy.

Second, there are derived predicates that show homogeneity. These are the predicates that are lexically collective but are shifted to a distributive interpretation via the addition of a D operator:

(11) a. The students received a gift.
 b. [The students [D received a gift]].

Under the collective interpretation of (11-a), the students received one common gift as a group. However, the sentence also has an interpretation where each individual student received a gift, and this is homogeneous, since in a situation with five students where only three of them got a pen each, (11-b) appears undefined. Assuming that the latter interpretation is derived via the addition of a D operator, then we have **derived** predicates that are systematically homogeneous. Križ 2019 takes the D operator to be responsible for introducing the homogeneity in these cases.

These exceptions open the possibility that homogeneity is not lexically specified, but rather predictable on the basis of distributivity, with cases like (7) involving hidden distributivity. In the rest of this paper, we explore this idea.

3 Broadening the empirical landscape

In this section we want to broaden the empirical domain by examining which collective predicates exhibit homogeneity. As Križ notes, measure phrases are

[4] Two entities x and y overlap iff there is z such that $z \leq x$ and $z \leq y$.
[5] See section 6 for more discussion on this.

collective predicates that behave in this way. Our claim is that in fact all collective states behave in this way, with measure phrases being just one example of a state. Furthermore, collective states share this behavior with collective achievements, which also do not exhibit homogeneity. This contrasts with collective activities and accomplishments, which do show homogeneity effects.

Consider the following collective states:

(12) a. The students are a productive team.
b. The books constitute a famous series.

Let us apply Križ's homogeneity generalization to (13-a). Imagine a situation where there are three students that are a productive team. Now, sometimes a fourth student joins the team, but the new team is not at all productive. Thus, we have a situation where (12-a) is not true of a plurality *a* (the four unproductive students), true of a plurality *b* (the three productive students) that overlaps with *a*, and in this situation (12-a) is plainly false, and not undefined, with 'the students' referring to *a*.

The same observation holds for (12-b), which can be true in a situation where there is a famous series of five books (plurality *a*), consisting fundamentally of three famous books that form the main series (plurality *b*), and two prequel novels that are not well-known at all. Nonetheless, the five books together (plurality *a*) can be truthfully said to constitute a famous series. No undefinedness arises.

Collective achievements pattern like collective states:

(13) a. The students elected a president
b. The senators passed the bill.

For (13-a) to be true, it is not required that all of the students elected a president. All that is required is that enough students participated in the electoral process in order for a president to be elected. For instance, imagine a class of 20 students who vote to elect a president. 15 students vote for John and 5 students abstain. 'elect a president' can be truthfully applied to the collectivity of 20 students that comprise the class, without any undefinedness arising. However, it is false to say only the 15 students who voted for John, or the 5 students who abstained, elected a president. The election is an effect of everyone participating. The same holds for (13-b): if a certain number of senators vote for the bill, then the bill passes even if not all of them vote.

Conversely, collective accomplishments, (14), pattern together with collective activities (i.e. 'perform *Hamlet*') in showing homogeneity:

(14) The girls built/did not build a raft.

Example (14) is true iff all the girls were involved or were not involved in the building of a raft. In a situation where 5 out of 10 girls were involved in the (collective) building of a raft, (14) appears undefined.

In sum, these additional data highlight a systematic connection between homogeneity and aktionsart:

(15) **Homogeneous Collective Predicates Generalization (version 1)**:
Collective activities/accomplishments show homogeneity;
collective states/achievements do not.

We now turn to the issue of connecting this aktionsart split to distributivity.

4 Brisson 2003 on Taub's generalization

Interestingly, homogeneity is not the only domain where the state/achievement vs accomplishment/activity split matters. The same generalization appears when we try to characterize which collective predicates allow 'all' (this is known as Taub's generalization, (Taub 1989)):

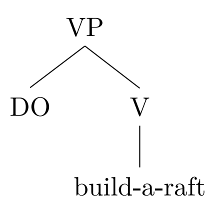
(16) a. All the students performed *Hamlet*
b. All the girls built a raft.
c. *All the students are a productive team.
d. *All the students elected a president.

(17) **Taub's Generalization:** The collective predicates that allow 'all' are collective accomplishments and collective activities. Collective states and colletive achievemnets disallow 'all'.

Brisson 2003 treats 'all' as being dependent on the presence of a D operator. If the predicate can host a D operator, then it can license 'all'. But how do we get 'all' to apply to collective achievements and activities, if we think that one of the hallmarks of collectivity is that collective predicates lack a D operator in their structure?

To capture the pattern in (16), Brisson makes a simple move. She claims that collective activities and accomplishments have more structure than collective achievements and states: they have an aspectual DO predicate (McClure 1994) which can host a D operator. States and achievements lack this predicate and hence cannot host a D operator.

(18)



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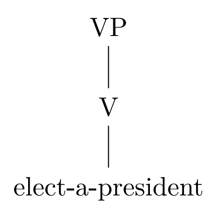


Brisson adopts an event-based framework, where VPs are predicates of events[6]. She also assumes that the domain of events is structured via a part-of relation, $\leq$. This leads to the following extensions:

(20) a. $||DO|| = \lambda x_e.\lambda e.DO(e) \wedge Ag(e,x)$
b. $||build-a-raft|| = \lambda e.build-a-raft(e)$
c. $||elect-a-president|| = \lambda e.elect-a-president(e)$

[6] Events are of type v

$||DO||$ and $||build\ a\ raft||$ combine via an operation that Brisson terms event composition[7]:

(21) If α is a branching node, $\{\beta, \gamma\}$ the set of its daughters, and $||\beta||$ is function of the form $\lambda e[P(e)]$ (type $\langle v, t\rangle$) and $||\gamma||$ is a function of the form $\lambda x_e.\lambda e[Q(x)(e)]$ (type $\langle e, vt\rangle$), then $||\alpha|| = \lambda x_e.\lambda e.[P(e) \wedge \exists e'[Q(x)(e')] \wedge e' \leq e]$

Applying (22) to (18) leads to the following result:

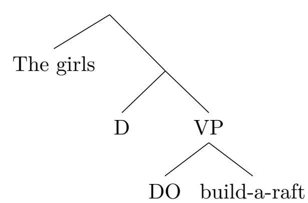
(22) $\lambda x_e.\lambda e.build - a - raft(e) \wedge \exists e'[DO(e') \wedge Ag(e', x) \wedge e' \leq e]$

We also assume a version of the D operator that can handle predicates of events[8]:

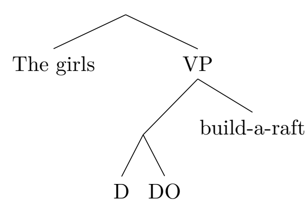
(23) $||D|| = \lambda P_{e,vt}.\lambda x_e.\lambda e.\forall y[y \leq_a x \rightarrow \exists e'[P(y)(e') \wedge Ag(e', y) \wedge e' \leq e]]$

By assumption, the D operator attaches to things that take a plural DP as a first argument. So, it can either attach to DO, or to the VP (i.e. to the result of event composition):

(24)



(25)



Interpreting (25) and (24), we get the truth conditions in (26-a) and (26-b) respectively[9]:

(26) a. $\exists e[\forall y[y \leq_\alpha \iota x.girls(x) \rightarrow \exists e''[build - a - raft(e'') \wedge \exists e'[DO(e') \wedge Ag(e', y) \wedge e' \leq e''] \wedge Ag(e'', y) \wedge e'' \leq e]]]$

b. $\exists e[build - a - raft(e) \wedge \exists e''[\forall y[y \leq_\alpha \iota x.girls(x) \rightarrow \exists e'[DO(e') \wedge Ag(e', y) \wedge e' \leq e''] \wedge e'' \leq e]]$

The truth conditions in (26-a) are the ordinary distributive interpretation, where each girl is required to have built her own raft (since for every girl there is raft-building event of which she is the agent). The truth conditions in (26-b) express a collective reading, where each girl was the agent of some DO-ing subpart of the raft-building event. All the girls still did something, but it was different sub-events in an overall raft-building event. This then gives us a way of formalizing the intuition that events like 'build-a-raft' have distributive sub-entailments (Dowty 1987): each girl participated in the raft-building by doing something.

[7] We formulate event composition assuming a Heim & Kratzer 1998 system.

[8] Brisson uses a Generalized D operator from Lasersohn 1998; We slightly adapt some things here to suit our own purposes. Nonetheless, Brisson's point is retained.

[9] A background assumption in (26), (37) is that every event has a unique agent.

Collective accomplishments and activities lack this DO predicate and therefore cannot host a D operator (and if one attempts to apply one on the VP level, then one ends up with distinctly odd truth conditions; see Brisson 2003 for details)

Therefore, the reason collective accomplishments and activities allow ‘all’ is the D operator that these predicates can host. Notice here that the analysis does not commit us exactly to Taub’s generalization, (17). Brisson’s analysis links the presence of ‘all’ to the presence of distributivity. Therefore, we need to revise (17) as follows:

(27) **Taub’s Generalization (revised):** The collective predicates that allow ‘all’ are those that can host a D operator somewhere in their structure.

Therefore, if we find collective states/achievements that allow ‘all’, we have not necessarily falsified (27). However, we do predict that collective states/achievements that allow ‘all’ involve the presence of a D operator. Reciprocals are a class of collective states that seem to function in this way:

(28) All the students look alike.

Reciprocals like ‘look alike’ are typically taken to involve quantification over parts[10]. If we take the source of this quantification to be some hidden distributivity operator, then such examples do not falsify (27), but rather confirm it.

5 Applying Brisson 2003 to homogeneity

The point that comes out of sections 3 and 4 is that distributivity and homogeneity have the same distribution. Applying Brisson’s idea that collective accomplishments/activities can host a D operator (on the DO part of their structure), whereas collective achievements/states cannot (because they lack this DO) leads us to revise the generalization in (15):

(29) **Homogeneous Collective Predicates generalization (revised):** The collective predicates that show homogeneity are those that can host a D operator in their structure.

What is homogenised in a collective accomplishments/activities such as ‘The students performed *Hamlet*’ is the DO-ing sub-events that each student is undertaking in the performance, e.g. performing the role of Hamlet for student a, being in charge of staging for student b etc.

Moreover, if Brisson is right that the presence of ‘all’ depends on the presence of distributivity, then by reducing homogeneity to distributivity we have a nice connection between the presence of ‘all’ and the presence of homogeneity, whereby only homogeneous predicates license ‘all’. This accords well with the claim that ‘all’ is a homogeneity remover (Kriz 2015, 2019):

[10] See Brisson 2003 and references therein for more details.

(30) The knights all died in battle.

The sentence in (43) is plainly false in a situation where only some of the knights died in battle, and not undefined. Thus, 'all' removes the undefinedness associated with homogeneity. This then constitutes another argument for the reduction we are pursuing: Homogeneity can be removed only from predicates that have it as a property. If 'all' is licensed only by predicates that involve distributivity, then homogeneity must only be present in predicates that involve distributivity.

As with the generalization in (27), our generalization in (29) is not limited to activities and accomplishments. Any collective predicate that involves distributivity qualifies. Consider reciprocals (see previous section):

(31) The students look alike.

(31) is homogeneous, as it is undefined in a situation where some students look alike, but others do not.

One issue that arises is how we can capture the way homogeneity works in negated sentences, where the requirement is that the property expressed by the VP not hold of any part of the subject:

(32) a. The knights did not die in battle.
b. The girls did not build a raft.

We propose to do this by making the following syntactic assumptions: First, in negated sentences, the D operator can only attach above negation[11]. Second, existential closure happens low, on the level of aspect (cf. Hacquard 2009).

These assumptions lead to LFs like the following[12]:

(33) [The girls [D [not [closure [build a raft]]]]]

To properly interpret these LFs, we need another D operator (call it D_2) in addition to the one in (23) (which we call D_1), that will combine with a negated predicate (of type *et*). We also need to define a closure operator that applies low. Finally, we need a meaning for negation. These additions, together with the rest of the lexical entries we need to interpret the sentence in (33), are included below:

(34) a. $||D_1|| = \lambda P_{et}.\lambda x_e.\forall y[y \leq_\alpha x \rightarrow P(y)]$
b. $||D_2|| = \lambda P_{e,vt}.\lambda x_e.\lambda e.\forall y[y \leq_\alpha x \rightarrow \exists e'[P(y)(e') \wedge Ag(e', y) \wedge e' \leq e]]$
c. $||closure|| = \lambda P_{e,vt}.\lambda x_e.\exists e[P(x)(e)]$
d. $||not|| = \lambda P_{et}.\lambda x_e.\neg P(x)$

(35) a. $||DO|| = \lambda x_e.\lambda e.DO(e) \wedge Ag(e, x)$
b. $||build\ a\ raft|| = \lambda e.build - a - raft(e)$

[11] We consider only predicate negation, leaving sentential negation to future research.

[12] We follow Gajewski 2005 in assuming that a distributive predicate has to combine with a D operator when it applies to a plurality.

c. $||the\ girls|| = \iota x.girls(x)$

We assume the lexical entries above, together with Brisson's system as presented in the previous section. We give the truth conditions for the following sentences:

(36) a. [The girls [closure [[D_2 DO] [build a raft]]]
b. [The girls [D_1 [not [closure [build a raft]]]]]

(37) a. $\exists e[build-a-raft(e) \wedge \exists e''[\forall y[y \leq_\alpha \iota x.girls(x) \rightarrow \exists e'[DO(e') \wedge Ag(e', y) \wedge e' \leq e''] \wedge e'' \leq e]]$
b. $\forall y[y \leq_a \iota x.girls(x) \rightarrow \neg\exists e[build-a-raft(e) \wedge \exists e'[DO(e') \wedge Ag(e', y) \wedge e' \leq e]]]$

The truth conditions in (37-a) say that for every atomic girl, there is a DO-ing event of which she is the agent, and that DO-ing event is part of a building event. (37-b) says that for no atomic girl is it the case that there is a raft-building event in which this girl did something. These are the truth conditions we want.

Finally, one might wonder how we capture the gappines of these sentences in mixed situations. We will say that a sentence α of the form [NP [(D_1) [closure VP]]][13] has the following truth conditions:

(38) a. α is True in a model M iff $||\ [NP\ [(D_1)\ [closure\ VP]]]\ || = 1$ in M and $||\ [NP\ [(D_1)\ [not\ [closure\ VP]]]]\ || = 0$ in M.
b. α is False in a model M iff $||\ [NP\ [(D_1)\ [closure\ VP]]]\ || = 0$ in M and $||\ [NP\ [(D_1)\ [not\ [closure\ VP]]]]\ || = 1$ in M.
c. α is undefined iff it is neither True nor False.

Consider now (36-a) in a situation where there are 5 girls, three of which participated in the building of a raft, while the other two did not. The truth conditions in (37-a) are not satisfied since it is not the case that for every atomic there is a DO-ing event of which that girl is agent, since 2 girls did nothing. Neither are the truth conditions in (37-b) satisfied, since it is not the case that no atomic girl is the agent of a DO-ing event that is part of a building event. Therefore, neither the positive nor the negative version of (36-a) is true, and the sentence is undefined in this scenario.

6 Comparison with Križ's homogeneity generalization

It is interesting to compare between the cases of homogeneity predicted by our approach and Križ's constraint in (8). Recall that (8) distinguished three cases of homogeneity: (i) downward homogeneity, (ii) upward homogeneity, and (iii) sideways homogeneity. Our approach predicts downward and sideways homogeneity, but not upward homogeneity. Let us go back to the raft-builidng example:

(39) The girls built a raft.

[13] The reason D_1 is in parentheses is that not every sentence will have a D_1 attached above closure, e.g. sentences with collective predicates.

(40) **Context:** Only a subgroup of the girls built a raft. (Downwards Homogeneity)

As we have seen, our approach predicts that (39) should be undefined in (40), since neither (39) nor its negation is true in (40).

(41) **Context:** Some of the boys together with some of the girls built a raft. (Sideways Homogeneity)

Our approach predicts that (39) should be undefined in (41): (39) is not true because the semantics in (37-a) requires that every individual girl participated in the raft-building. (37-b) is not true because there are individual girls that participated in the raft-building.

(42) **Context:** Both the boys and the girls participated in the raft-building. (Upward Homogeneity)

Our approach predicts that (39) should be true, since for every individual girl, that girl participated in the raft-building (which makes (37-a) true and (37-b) false).

Therefore, our approach groups together downward and sideways homogeneity, to the exclusion of upwards homogeneity.

While further research is required into the status of these three homogeneity types, it should be mentioned that there is at least one case where downward homogeneity contrasts with upward homogeneity. While 'all' removes downward homogeneity, it does not remove upward homogeneity (Križ 2015):

(43) All the girls built a raft.

Even though (43) is false in (40), it is still undefined in (42). On the other hand, the addition of 'only' removes upward homogeneity, but not downward homogeneity:

(44) Only the girls built a raft.

(44) is plainly false in (42), but still undefined in (40)[14]. This suggests a parallel with scalar implicatures:

(45) **Context:** All of the students of a class ran in a race.
a. #Some of the students ran in the race.
b. Only some of the students ran in the race.

While (45-a) seems weird in the given context, it is not false, merely under-informative. (45-b) on the other hand, is clearly false. One could imagine then that the reason (39) is odd in (42) is that it is under-informative to claim that the girls built a raft in a context where all the boys and all the girls built a raft.

[14] Interestingly, (43) and (44) seem both false in (41), suggesting that sideways homogeneity has a somewhat mixed status between upward and downward homogeneity.

7 Conclusion

In this paper we have argued for a reduction of homogeneity to distributivity. We noticed that while collective activities and accomplishments license homogeneity, collective states and achievements do not. The same aktionsart split is found with the collective predicates that allow 'all'. We followed Brisson 2003 who argues that collective activities and accomplishments have a DO predicate as part of their structure that can host a D operator. Collective states and achievements lack this DO and hence cannot host a D operator. We used this to formulate the generalization that the collective predicates that allow homogeneity are those that can host a D operator and developed a semantics for homogeneity (following again Brisson) whereby homogeneity arises as an effect of distributvity (together with certain assumptions about the syntax of D). Finally, we showed that while our account captures downward and sideways homogeneity, it cannot capture upward homogeneity, and made the tentative suggestion that upward homogeneity might be due to Gricean reasoning.

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