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The interaction of question particles and negation in embedded contexts: the case of *alles*[*]

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Abstract The German question particle *alles* 'all' (Reis 1992; Zimmermann 2007) is characterized in the semantic literature as imposing plurality and exhaustivity requirements on the answer space. I report on novel experimental evidence probing the interaction of *alles* and negation in embedded questions. I investigated *alles* under three embedding predicates: *vergessen* 'forget', *wissen* 'know', and *überraschen* 'surprise'. The data show that *alles* may contribute to at-issue content, on the basis of its interaction with negation.

Keywords: exhaustivity, embedded questions, question semantics, German, quantification

1 Introduction

The QQP (Question Quantifying Particle; Zimmermann 2007) *alles* is typically characterized in the semantic literature as contributing exhaustivity (though also plurality and/or maximality, cf. Beck & Rullmann 1999; Zimmermann 2018; Reis 1992). The purpose of this experimental investigation is to add to an empirical basis upon which these theoretical claims may be evaluated. The example below illustrates the primary intuition native speakers of German have regarding *alles*; the answer given is infelicitous because *alles* requires an exhaustive listing of presenters.[1]

(1) a. Q: Wer hat alles bei SuB11 vorgetragen? (Zimmermann 2007: 631)
Q: who has *alles* at SuB11 presented?
'Q: Who *alles* presented at SuB11?'

b. A: # Ein MIT-Student und Gennaro Chierchia.
A: # an MIT-student and Gennaro Chierchia.

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1 This example may be odd under a mention-some reading more generally, also without *alles*. A reviewer points out that, in listing more than a single answer, the speaker implies that their answer is not mention some and should be given a more exhaustive interpretation (cf. Xiang 2016).

‘A: # An MIT-student and Gennaro Chierchia.

In the experiment reported here, I attempted to establish whether or not *alles* can be made at-issue by probing its interaction with negation, embedded under three verbs: *vergessen* ‘forget’, *wissen* ‘know’ and *überraschen* ‘surprise’. The null hypothesis is as follows: if *alles* cannot be made at-issue, seeing as embedded interrogatives are homogeneous, there should be a null result across conditions despite the negation manipulation. Alternatively, different response patterns under the embedders, due to their varying monotonicity and distributivity properties, would be grounds to reject the null hypothesis.[2]

1.1 Previous accounts

In the literature, *alles* is typically described as a marker of exhaustivity (Beck & Rullmann 1999; Zimmermann 2007). Beck & Rullmann (1999) consider *alles* to be truth-conditionally active: it overtifies the *answer1* operator, taking the question denotation as input and yielding the conjunction of true propositions, equivalent to a WE (Weakly Exhaustive) reading.[3] Zimmermann (2007) argues on the basis of scopal data that the analysis in Beck & Rullmann 1999 does not stand up to further empirical scrutiny. The crucial insight in Zimmermann 2007 for our purposes is that *alles* cannot operate on the set of propositions comprising the question domain but instead must operate in a local construal with the set of individuals denoted by the wh-item. Zimmermann (2007) proposes that the contribution of *alles* is presuppositional in nature, requiring that the question domain contain plural (divisible) individuals and that it be exhaustive (the domain is restricted to *maximal*, divisible individuals).

Previous accounts also vary in terms of whether they consider *alles* to be focusable or (optionally) at-issue: Zimmermann (2007) draws explicit parallels between *alles* and prototypically focus-sensitive operators. Reis (1992), on the other hand, claims that *alles* is not truth-conditionally active and cannot be focus-accented. Ability to bear focus and be targeted by negation are hallmarks of at-issue content (Esipova 2018; Tonhauser 2012), but the former does not entail operating at the level of truth-conditions (Simons 2005; Craige Roberts & Tonhauser 2009).

2 *know* being upward entailing, *forget* Strawson-downward entailing and *surprise* downward entailing/non-monotone (Cremers 2018).

3 An earlier account in Beck 1996 also takes *alles* to be an exhaustivity marker resulting in mutually exclusive, exhaustive answers.

1.2 Syntactic assumptions

What the above-mentioned accounts have in common is that they take it that *alles* imposes restrictions on the domain of the question. *Alles* may be contrasted with the quantifier *alle* in this respect, which despite similar appearances, has different effects in questions.[4] *Alles* quantifies directly over the wh-word or its trace, whereas declined *alle* instead quantifies over the restrictor NP (Reis 1992; Zimmermann 2007; Doliana 2019); as seen in (2) from Doliana 2019: 7.

(2) a. Wessen Münzen sind alle auf Kopf gelandet?
whose coins are *alle* on head landed
'Whose coins all landed on heads?'

b. Wessen Münzen sind alles auf Kopf gelandet?
whose coins are *alles* on head landed
'What are all the people for which (some) coins have landed on heads?'

1.3 Exhaustivity or completeness?

It has been argued that *completeness* is a better characterization of the semantic contribution of *alles* as it does not enforce the types of readings termed Strongly Exhaustive (SE) under all embedders (Theiler 2014). The felicitous example below from Theiler 2014: 53 would come out as contradictory if *alles* forced an SE reading under which him telling me which of his friends he *all* saw would entail him telling me which of his friends he did *not* see.

(3) Er hat mir erzählt wen seiner Freunde er gestern alles gesehen hat,
he has me told who his.GEN friends he yesterday *alles* seen has,
aber er hat mir nicht erzählt wen er nicht gesehen hat.
but he has me not told who he not seen has
'He told me who *alles* of his friends he saw yesterday but did not tell me who he did not see.'

1.4 Main claims and structure of paper

I provide evidence for two primary claims. First, *alles* is visible to negation, so its contribution can be made at-issue (*pace* Reis 1992). Second, *alles* functions as a homogeneity remover in embedded questions. In Section 2, I begin by explicating the motivation behind the experimental paradigm and provide the requisite theoretical background on embedded questions. Next, in Subsection 2.1, the experimental

4 I refer the reader to Reis 1992 and Doliana 2019 for more on the contrast between the two.

design and predictions are presented. In Section 3, the experimental results are presented alongside a discussion of the primary findings. The second half of the paper begins in Section 4 with a discussion of the desiderata for an analysis of *alles* followed by the analysis itself. Section 5 contextualizes the homogeneity removing properties of *alles*. Finally, Section 6 concludes with future research directions.

2 Theoretical Background in a Nutshell

I assume a view of questions as laid out in von Fintel & Heim 2001 and Elliott, Sauerland & Nicolae 2020 (in turn based on Karttunen 1977 and Hamblin 1973): the meaning of a question involves a complete list of true answers, that is, a set of propositions.[5] Most accounts of embedded questions encode maximality into the denotation of the answerhood operator, which functions as the interface between the embedder and the Hamblin set denoted by the wh-clause; this covert *ANS* operator picks out the maximally informative answer from this proposition set (Rullmann 1995; Dayal 1996).

It is desirable to capture the parallels between embedded interrogatives and plural definite descriptions: both display homogeneity effects. The parallels between them are made clear looking at the entry for an answerhood operator *ANS* in Dayal 1996 reproduced in (4), where the ι-operator selects *the* unique maximal answer proposition. Definite descriptions and embedded questions additionally share a number of other properties, such as cumulativity and quantificational variability effects (see Cremers 2018; Gajewski 2005).[6]

(4) $ANS_w(\mathrm{Q}) = \iota p \in Q[p(w) = 1 \wedge \forall q \in Q\ [q(w) = 1 \rightarrow p \subseteq q]]$

Homogeneity can be defined in general terms as follows (see Magri 2014; Löbner 2000; Bar-Lev 2020; Križ 2016; Cremers 2018 for more perspectives). Plural definites receive a universal interpretation in positive contexts but seemingly receive an existential interpretation under negation. In (5), it follows that (a) is equivalent to (c) but not (b) (example adapted from Magri 2014).

(5) a. Daisy didn't see the dogs (#but she did see some of them).

b. Daisy didn't see each of the dogs (but she did see some of them).

c. Daisy didn't see any of the dogs (#but she did see some of them).

5 I take it that wh-phrases are existential quantifiers and assume a proto-question operator to derive the Hamblin set. This is elucidated further in Section 4.

6 The effect of *alles* in these environments is a potentially fruitful future research direction. Notably, *alles* is not compatible with either QVE or cumulativity, based on introspective judgements.

Under a trivalent view of homogeneity as in Križ 2015, the predication of a predicate P of a plurality X results in truth or falsity iff either all or none of the members of X satisfy a property P; otherwise it results in indeterminacy.

2.1 Experimental Design

Materials The design is a 2x2x3 with the factors being $[+/-alles]$ and $[Neg1/2]$ (position of negation in first or second conjunct) under three different embedders: *wissen* 'know', *vergessen* 'forget' and *überraschen* 'surprise'.[7] These predicates were chosen due to their varied entailment and distributivity characteristics. A forced-choice paradigm was used to test for contradictions, asking participants "Does the text above make sense?" with two possible options "Yes, it makes sense" or "No, it doesn't make sense".[8]

The key observation for this experimental paradigm is as follows: *alles* seems to dissolve homogeneity. In the example below under 'know', a follow-up mentioning an atomic answer is licit if the negation of the *wer-alles* phrase in (6a) in the $[+alles/Neg1]$ condition targets the complete answer but not necessarily its atoms (Löbner 2000; Križ 2016).[9] The prediction is that (6b), the $[-alles/Neg1]$ condition, would come out contradictory due to homogeneity. Moreover, if *alles* is visible to negation, it can be made at-issue.[10]

(6) a. David weiß nicht, wer alles Kuchen gegessen hat. Er weiß aber, dass Sonja Kuchen gegessen hat.
David knows not, who *alles* cake eaten has. He knows though, that Sonja cake eaten has.
'David does not know who *alles* ate cake. He does know that Sonja ate cake, though.'

b. David weiß nicht, wer Kuchen gegessen hat. Er weiß aber, dass Sonja Kuchen gegessen hat.
David knows not, who cake eaten has. He knows though, that Sonja cake eaten has.
'David does not know who ate cake. He does know that Sonja ate cake, though.'

7 Henceforth I refer to these predicates in English for ease of exposition.

8 In the original: "Ergeben die Sätze oben Sinn?"

9 I use atomic answer here in the sense of Cremers 2018; atomic answers can be defined in relation to Hamblin sets.

10 An anonymous reviewer claims that our main conclusion can be challenged if we are dealing with meta-linguistic focus and, as a result, meta-linguistic negation (in the sense of Horn 1985) targeting the assertability of the utterance, which would not point to *alles* being at-issue. It is not clear, however, whether homogeneity removal would be predicted to follow in such a case.

The design was a counterbalanced Latin square in which each participant saw one list per verb, list-assignment was random and items were presented in a pseudo-randomized fashion. The experiment consisted of 48 target items (16 per verb) and 48 fillers (1:1 ratio, 96 total). The fillers were used as baselines, including contradictions such as: *Hans hasn't forgotten that yellow sunglasses were distributed, but he has forgotten that sunglasses were distributed*.[11] Items were presented "out-of-the-blue" without any additional context. Participants first provided their consent, received general instructions and completed a short practice round.[12]

Participants 37 experimental participants were recruited via the University of Potsdam's SONA recruitment portal. All participants self-designated as native speakers of German. The data-set includes 31 participants, 6 others were excluded due to less than 75% accuracy on baseline controls.

2.2 Predictions

Know The predictions for *wissen* 'know' are based on its upward entailingness and distributivity. It was predicted that $[+alles/Neg1]$ would result in better judgements than $[-alles/Neg1]$. The presence of this contrast would additionally provide evidence for *alles* as a marker of exhaustivity or completeness, seeing as the only parse of the $[+alles/Neg1]$ condition where it comes out as non-contradictory is one where the complete answer is what gets negated, as illustrated in (6) above.

Forget Under *vergessen* 'forget', the opposite response pattern to that of *know* was predicted. *Forget* is downward entailing as well as distributive. Under common assumptions, it asserts current oblivion and presupposes prior (non-false) belief (Cremers 2018: 225). It was therefore predicted that (7) would come out better than the corresponding example without *alles*.[13]

(7) Rosalinde hat vergessen, wer alles beim Film gegähnt hat. Sie hat
Rosalinde has forgotten who *alles* at.the movie yawned has. She has
aber nicht vergessen, dass Thorben beim Film gegähnt hat.
but not forgotten, that Thorben at.the movie yawned has.

---

11 This is condition (c); $[NEG2]$/$[+SS]$ as shown in Fig. (1). The manipulation was whether the superset appeared in the first ($[+SS]$) or second ($[-SS]$) conjunct, as well as the position of negation $[Neg1/2]$. The order of the conditions shown in (1) is: **a.** $[Neg1/+SS]$, **b.** $[Neg1/-SS]$, **c.** $[Neg2/+SS]$, **d.** $[Neg2/-SS]$

12 Due to experimenter error, two items under *forget* were removed from the data prior to analysis.

13 This is the (b) condition: $[+alles/Neg2]$; here, oblivion pertains to the complete answer.

‘Rosalinde has forgotten who *alles* yawned at the movie. She has not forgotten that Thorben yawned at the movie, though.’

Surprise I assume that the denotation of *überraschen* ‘surprise’ has two components (Guerzoni & Sharvit 2007; Cremers 2018): it both presupposes that p is true and x knows p, and it asserts x expected p not to be true. Unlike *know* and *forget*, *surprise* does not obligatorily exhibit homogeneity effects in positive contexts (Zimmermann 2018).

This would be unexpected were *surprise* distributive, but this does not appear to be the case (Lahiri 2002; Sharvit 2002). *I'm surprised that Bob and Mary came to the party* does not license the inference that *I'm surprised that Bob came to the party*. The sentence in (8) is true in a context in which one specific child came to the party (Cremers 2018).

(8) It surprised Chris which children sang. (Cremers 2018: 231)

Under the scope of negation, *surprise* does exhibit homogeneity. The main intuition as pointed out by Zimmermann (2018) is as follows: *not surprise* should be infelicitous if it is *not* the case that all alternatives are unexpected.

(9) # It does not surprise David who ate cake, even though he is surprised that Chris ate cake.

Introspective intuitions suggest that homogeneity violations with surprise in positive contexts are possible though somewhat marked.[14]

(10) It surprised David who ate cake, even though he is not surprised that Chris ate cake.

Under *surprise*, *alles* makes the object of surprise the "overall composition" of a group/maximal entity (Theiler 2014). Let us situate ourselves in the following context (due to Zimmermann 2018): "Tarantino is shooting a new movie. This time, he didn't only cast the usual suspects, but also some unknown lay actors". In such a non-homogeneous context, the sentence is odd without *alles*.[15]

(11) Es überrascht mich, wen Tarantino #(alles) gecasted hat.
It surprises me, who Tarantino #(*alles*) casted has.
‘It surprises me who Tarantino #(*alles*) casted.’

14 It seems to matter what kind of contrastive marking is used here, in English *but* is infelicitous but *though* is fine. The experimental items used German *aber*.

15 The presence of *alles* allows for (more highly marked and logically weaker) non-homogeneous readings, so it can be tied to economy considerations (cf. Cremers & Chemla 2016; Guerzoni & Sharvit 2007; Zimmermann 2018).

This can be compared to a more prototypical homogeneous *surprise* context (from Zimmermann 2018), in which (12) is uttered: "This year's Academy Awards were full of surprises. None of the favorites got an award". The example is not felicitous if *alles* is present.

(12) Es überrascht Joe, wer (# alles) ausgezeichnet wurde.
It surprises Joe, who (# *alles*) awarded became.
'It surprises Joe who (# *alles*) got awarded.'

In summary, with *alles* present, it was predicted that homogeneity would become void and hence make such sentences felicitous regardless of the position of negation. Concretely, it was predicted $[+alles/Neg1]$ would be better than $[-alles/Neg1]$, and $[+alles/Neg2]$ would come out better than $[-alles/Neg2]$.[16]

3 Results

Inferential statistics Separate generalized linear mixed-effects models were fit in R (R Core Team 2019) using lme4 (Bates, Mächler, Bolker & Walker 2015) for each embedder. Fixed effects were *alles* and *negtype*. Random effects included an intercept for item and there was a by-subject slope for the factor *alles*.[17]

Post-hoc pairwise comparisons were computed for the contrasts of interest using *lsmeans* (Lenth 2016). For *know*, the contrast between $[+alles]$ and $[-alles]$ in $[Neg1]$ was found to be highly significant (p<.001) (the comparison in $[Neg2]$ was not significant, p=0.988). For *forget*, the contrast between $[+alles]$ and $[-alles]$ in $[Neg2]$ turned out to be highly significant (p<.001) (the comparison in $[Neg1]$ did not reach significance, p=.16). For *surprise*, the $[+/-alles]$ contrast was highly significant in both $[Neg1]$ and $[Neg2]$ (p<.001).[18]

16 Moreover, *surprise* is often taken to be focus-sensitive (Villalta 2008; Romero 2015). Since prosody was not controlled for, it can be assumed that when *alles* is there, it receives focus-accent.

17 This is the most maximal model that converged. Inclusion of the slope was justified by model comparison. Model specification is as follows: response $\sim$ alles * negtype + (1 + alles | subject) + (1 | item). Contrasts were sum-coded. P-values obtained by maximum likelihood. The results reported here differ slightly from the poster due to manual error which resulted in 3 participants who should have been excluded not having been. All plots were generated via ggplot (Wickham 2016). The full scripts and stimuli can be found at https://osf.io/dx5hm/

18 These were computed using the tukey method for a family of estimates.

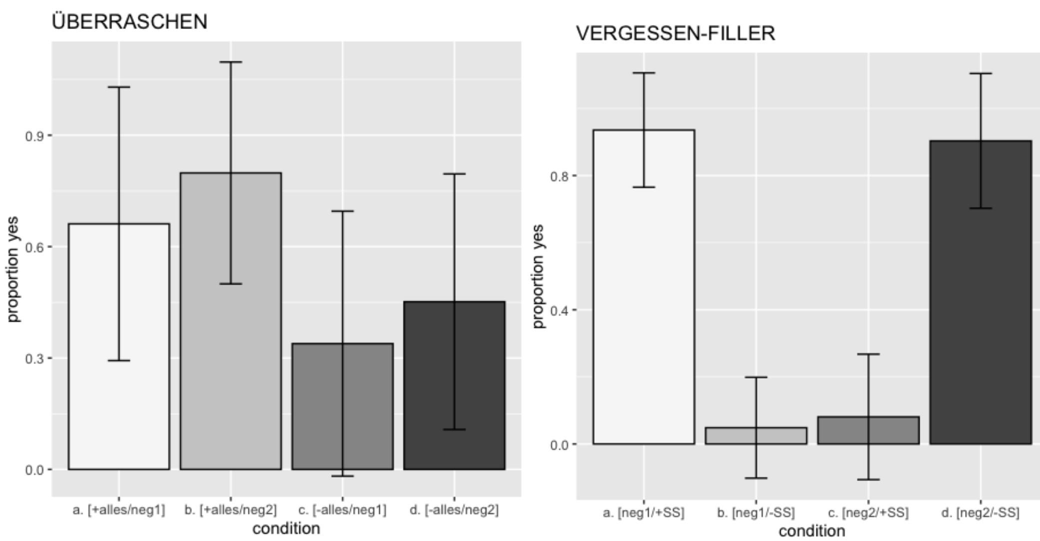

Figure 1 Results for *überraschen* ‘surprise’ on the left and for fillers under *vergessen* ‘forget’ on the right.

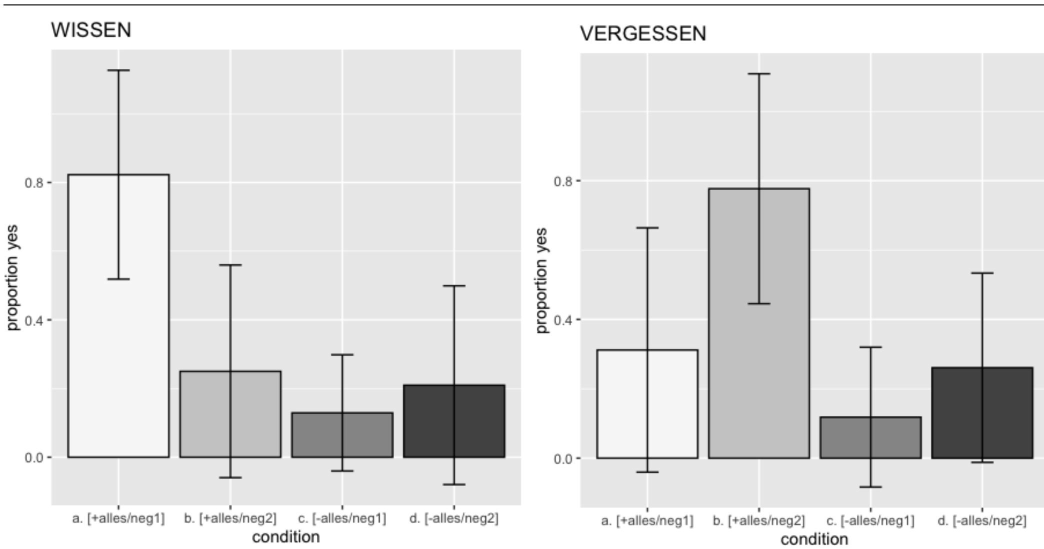

Figure 2 Results from *wissen* ‘know’ on the left and *vergessen* ‘forget’ on the right.

	Know	Forget	Surprise
alles1	2.509***	2.391***	2.374***
	(0.447)	(0.529)	(0.431)
negtype1	1.601***	−2.305***	−1.054***
	(0.328)	(0.345)	(0.270)
alles1:negtype1	4.682***	−2.112***	−0.341
	(0.664)	(0.678)	(0.519)
Constant	−0.964***	−0.834***	0.535
	(0.324)	(0.314)	(0.392)
Log Likelihood	-214.315	-201.099	-251.888
Akaike Inf. Crit.	444.631	418.199	519.776
Note:	*p<0.1; **p<0.05; ***p<0.01		

Figure 3 Results from generalized linear mixed models for each embedder; SE in brackets

3.1 Discussion

Main predictions verified: *alles* is visible to negation and the response patterns with *know* and *forget* mirror one another. Fillers successfully served as controls.[19]

Observation 1: Both [+*alles*] conditions under *surprise* were rated acceptable; there is no homogeneity to begin with so the effect of *alles* is presumably to bias towards the group-composition reading.[20]

Observation 2: *Surprise* is not as degraded as *forget* in the [−*alles*] conditions despite both typically considered to be downward entailing; this may be accounted for in light of differences in distributivity.

Observation 3: Contradictions in the fillers patterned differently than the lower bound of acceptance for targets, as seen in Figure (1). Noise in the data may account for this, due to a lack of sufficient domain restriction in the experimental items (cf. George 2011).

19 Schematically, the experimental conditions are as follows, they are presented in this order on the plots: **a.** [+*alles*]/[*Neg*1], **b.** [+*alles*]/[*Neg*2], **c.** [−*alles*]/[*Neg*1], **d.** [−*alles*]/[*Neg*2]

20 It must be noted that this preliminary conclusion is based on introspective intuitions such as those presented in the previous section.

3.2 Interim conclusion

The experimental data provide evidence that *alles* is visible to negation and can therefore be made at-issue. Moreover, the experimental data confirm what has been previously reported in the literature about *alles* being able to remove homogeneity (Križ 2015). Taken together with the locality facts discussed in Reis 1992 and Zimmermann 2007, there are two remaining puzzles to be accounted for in the second portion of the paper. Firstly, the relevant locality restrictions must be derived: *alles* requires a local construal with the wh-item. Secondly, the mechanism of homogeneity removal must be explicated in terms of how it relates to the requirements *alles* imposes on the question domain.

4 Analysis of QQP *alles*

In this section, I provide an analysis for the QQP *alles*. I begin by delineating my assumptions regarding the semantics of questions and provide an analysis which maintains a principled connection between *alles* and the wh-item, conforming to the strict locality constraints *alles* is subject to as well as providing an avenue for deriving homogeneity removal by means of imposing restrictions on the makeup of the alternative set.

4.1 Analysing *alles*

There are a number of desiderata for an analysis of question-internal *alles*:

1. *alles* must be in a local relationship with the wh-word or trace. This follows from both syntactic and semantic considerations. For instance, *alles* only removes homogeneity for the argument position with which it is co-indexed (Reis 1992; Zimmermann 2007; Doliana 2019).
2. *alles* operates in the domain of individuals. It does not operate over propositional meaning (Zimmermann 2007).[21]
3. Descriptively speaking, *alles* partitions the answer space in such a way that only non-atomic, complete answers are licit (Zimmermann 2007).

4.2 Assumptions: Question semantics

In order to account for the locality facts discussed for *alles* above, I take it that there is a strictly local relationship in the syntax between *alles* and the wh-item and

21 This provides an explanation for why *alles* is not licit in contexts such as degree questions, i.e. *how fast can I drive here?* These already implicate maximality as part of the semantics (Rullmann 1995).

that the mechanism of local contribution comes about by means of reconstruction. I build upon Schwarz, Hirsch & Socolof 2020 and Hirsch & Schwarz 2019 in assuming that there may be both an overt and covert wh-word. The covert-wh, wh∃, in (13) originates as the first argument of the overt wh-word and moves to a specifier position above C. The overt-wh, seen in (14), reconstructs into the question nucleus, composing with its restrictor and verb at TP level.[22]

(13) $[\![\text{wh}\exists]\!] = \lambda f_{e,t}\ \exists x[f(x)]$

Below in (14) is an entry for an *overt* version of *which*.[23] By taking this approach, it can be ensured that the meaning contribution of *alles* only applies to the argument position with which the wh-phrase associates syntactically.[24] The result of applying overt-wh gets existentially bound by wh∃.

(14) $[\![\text{which}]\!] = \lambda x_e.\lambda f_{et}.\lambda g_{et}.\ f(x) \wedge g(x)$

For the computation to be carried out, we also need to assume the following definition for a proto-question operator in C, to yield the requisite propositions in the Hamblin set.

(15) $[\![\ ?\ ]\!] = \lambda q_{st}\lambda p_{st}.p = q$

The structure of the question is, then, as shown in (16).

(16) [CP λp [wh∃ λx [C' [C ? p] [TP [DP [which x] restrictor] [VP]]]]]

Since *alles* displays a collective-distributive ambiguity I assume that plural predication can make use of covers, ways of partitioning the domain which do not (necessarily) correspond to atoms (Schwarzschild 1996: 69).[25] These covers are variables introduced by a covert distributivity operator as shown below in (17).[26]

(17) $[\![\text{DIST}]\!] = \lambda P.\lambda x.\forall z[z \leq x \wedge \text{Cov}(z) \rightarrow P(z)]$

(18) C covers X iff: (Xiang 2016: 53)

a. Cov is a set of subparts of X

22 See Rullmann & Beck 1998 for more on reconstruction.

23 It is worth mentioning that while I have thus far only discussed *wer alles* 'who all', the configuration 'which NP *alles*' is also licit in German (cf. Reis 1992).

24 In Schwarz et al. 2020 this entry comes along with a maximality presupposition which I omit here.

25 Why not treat *alles* itself as an overt instantiation of a distributive operator? The primary argument in favour of not going this route is that covert elements cannot be focus accented or made at-issue, unlike *alles* (cf. the comparison of Hungarian fronted focus and the overt exclusive *csak* 'only' in Szabolcsi 1994). One more consideration is that *EXH* operates on the propositional level, not locally like *alles*.

26 Following the account in Schwarzschild 1996, this is a VP-modifier.

b. every subpart of X belongs to a member in Cov.

In order to capture the plurality requirement associated with *alles*, I adopt the following definedness condition.

(19) ⟦alles⟧ (ϕ) is defined iff the cover of ϕ contains divisible non-atomic individuals (Zimmermann 2007: 636)[27]

Finally, I follow Brisson (2003) in treating *alles* not as a quantifier, but rather as a domain restrictor, the meaning contribution of which is to constrain the internal structure of the entity over which it operates.[28] The requirement it imposes on its domain is that of *good fit*, defined in (20). Recall as well that *alles* is subject to an LF locality condition such that it must be the sister to the wh-pronoun or trace at LF (cf. Zimmermann 2007; Doliana 2019).

(20) For some cover *Cov* and some entity X, *Cov* is a *good fit* iff:
$\exists Z[Z \in Cov \wedge \forall y[\text{Atom}(y) \wedge y \leq X \rightarrow y \leq Z]]$ (Brisson 1998: 94)

Now, let us look at a simple example involving a distributive predicate *eat*, in a context where the domain consists of three students: *A*nna, *B*enni and *C*harlie, so $D = {*}\{a,b,c\}$.

(21) Welche Studenten haben alles zu Mittag gegessen?
which students have *alles* to lunch eaten?
'Which students *alles* ate lunch?'

Below, I use MAX as a shorthand to designate the requirements on *good fit* with regard to contextual covers imposed by *alles*. The CP level derives a set of propositions as follows:

(22) $[\![\text{CP}]\!]^{g,w} = \lambda p_{s,t}.\exists x[p = \lambda w'.MAXstudents_{w'}(x) \wedge ate_{w'}(x)]$

Given the world of evaluation, the distributivity of the predicate in question, and the good fit requirement which states that there is a member of the cover which contains every member of the plurality in question, the answer set contains the singleton in in (23). This results in a WE reading.

27 See Zimmermann 2007 for reasoning as to why a cardinality requirement does not suffice.

28 Here *alles* is not a truth-conditional operator, but the *good fit* requirement also does not seem to project like a presupposition (Brisson 1998: 210). The effect of *alles* is rather to prevent certain possible contexts from being entertained as possibilities for interpretation. Zimmermann (2007) provides arguments for the presuppositionality of *alles*, one of which being that the plurality requirement can be cancelled by an answer containing *nur* 'only'. The second argument provided in Zimmermann 2007 is that *alles* cannot be targeted by negation, however the experimental results here contradict this latter point.

(23) $\lambda w'.ate_{w'}(a \oplus b \oplus c)$

It is illustrative to compare this result to the corresponding answer set without the presence of *alles*. Without *alles*, the answer set contains atomic individuals: {a ate, b ate, a$\oplus$b ate}. If I take it that an answerhood operator (as in (4)) is present in non-embedded environments, it becomes apparent that the strongest proposition output both with and without *alles* is identical. On its own, this does not allow us to account for homogeneity nor its removal. In Section 5, I extend this system to embedded environments under factives like *know*, integrating insights on mechanisms of homogeneity removal.

5 Homogeneity removal

In this section I show how the account in Križ & Spector 2020 provides an avenue for explaining how *alles* removes homogeneity in embedded contexts, drawing on reasoning about sub-alternatives of a domain. Homogeneity can be tied to plural predication in general (Löbner 2000), whereas homogeneity *removal* arises when there is universal quantification implicated in the structure, as opposed to plural predication (Križ 2015). Crucially, in order to derive homogeneity removal given the account of *alles* in the previous section, we need a theory of homogeneity which is sensitive to the makeup of alternative sets. The analysis in Križ & Spector satisfies this requirement. We can apply the same principle of homogeneity removal in plural definites to embedded interrogatives. Before doing so, I will proceed to outline in more detail how the system in Križ & Spector works to derive homogeneity in declarative contexts. In 5.1, their account is applied to unembedded interrogatives. In Section 5.2, the analysis is extended to embedded contexts under factives. Section 5.3 concludes by showing how the analysis of *alles* provided above in Section 4 results homogeneity removal under this system.

On the account in Križ & Spector, plural predication denotes candidate interpretations (building on the approach in Malamud 2012). A candidate *denotation*, which combines with the predicate to form an *interpretation*, is "any disjunction of the mereological parts of the restrictor plurality". Candidate denotations are hence ways in which a definite description can be interpreted. They are generalized quantifiers, so the candidate denotation x is equivalent to the Montagovian individual of the form $\lambda P.P(x)$.

There are a few components of the analysis in Križ & Spector which need to be introduced before proceeding. The first of which is the interpretation function which is relativized to a model, a variable assignment, a world and a homogeneity parameter $\mathscr{H}$. This parameter takes two arguments: an argument index and an individual. For any value of $\mathscr{H}$, the output is a candidate denotation; this is a generalized quantifier based on the individual. The source of homogeneity on Križ & Spector's (2020) account is low: the parameter $\mathscr{H}$ generates quantifiers and the logical relations between alternatives depends on what this parameter is resolved to (defined as disjunctions; see also Bar-Lev 2020 for an account which is conceptually similar in this respect). Homogeneity arises due to the construal of candidate denotations and the predicate; these propositions are termed candidate interpretations (see Löbner 2000 and Križ 2016 for arguments that homogeneity as a property of the predicate). The main idea behind this is that homogeneity comes about when an a sentence is true on all of its candidate interpretations. That is, for all values of the parameter.

In Križ & Spector, candidate *denotations* are notationally represented as individuals. I will follow them here for ease of exposition. The output candidate *interpretations* are all of the propositions arising from a sentence containing the plural definite "the NPs" $\in Cand_x$.[29] Represented below in (24) is a spell-out of $Cand_x$, where $Part(x)$ represents mereological parts of x (which need not be atomic). A homogeneity parameter is a function that is well formed iff for all numbers (argument indices) n and individuals x, $\mathscr{H}(n,x) \in Cand_x$.

(24) $Cand_x := \{\bigvee S | S \subseteq Part(x) \wedge \forall y \in Part(x)\text{: } (\exists s \in S : \text{s} \sqsubseteq y) \rightarrow y \in S\}$

In order to derive the candidate denotations, one inputs all possible values for the parameter $\mathscr{H}$. If it is assumed that the extension of "students" is world-independent and there are 2 students, $\{a,b\}$ the resulting candidate denotations are as shown in (25).

(25) a or b or $a \oplus b$
a or $a \oplus b$
b or $a \oplus b$
$a \oplus b$

The next step is to apply the predicate to derive the relevant propositions. Since we are interested in distributive predicates, a distributivity operator needs to be introduced here as well. As it is formulated in (17) and under the assumptions in Križ & Spector, quantifying over parts of a plurality would break the homogeneity introduced by the verb. Nonetheless, homogeneity is still exhibited by distributive predicates on the phrasal level. This is achieved in Križ & Spector by introducing an argument index on the operator to allow candidate formation to proceed once again.[30] Let us apply a distributive predicate to the candidate denotations in (25),

29 Presupposing that these candidates stand the test of contextual relevance. The matter of relevance for (non-)maximality is discussed in Malamud 2012 and Križ & Spector 2020.

30 On Križ & Spector's account it follows that the candidate based on an atomic individual corresponds to that lifted individual, so the index does not affect the interpretation here.

assuming the LF in (26a) with a distributivity operator identical to (17) except for it being relativized to the parameter $\mathscr{H}$, shown in (26b).

(26) The students ate.

a. $[\![\text{the students DIST}_i \text{ ate}_j]\!] = [\![DIST_i]\!]^{w,\mathscr{H}}([\![ate_j]\!]^{w,H})(\mathscr{H}(i,\oplus students'_w))$

b. $[\![DIST_i]\!]^{w,\mathscr{H}}([\![ate_j]\!]^{w,\mathscr{H}}) = \lambda x.\forall z[z \leq x \wedge Cov(z) \rightarrow ate'_w(z)]$

The predicate combines with ($\mathscr{H}(i, \oplus students'_w)$), which is a set of disjunctive alternatives (of the form $D_i \vee ... \vee D_n$). As a result, (26a) is true iff the predicate is true of any D_i and there is a D_i such that every Cov of D_i is in ate'_w. If the domain consists of {a, b, a⊕b} as in (25), the resulting propositions are shown in (27).[31]

(27) {a or b ate, a ate, b ate, a ate and b ate}

5.1 Application to interrogatives

Typically it is assumed that the interrogative domain consists of sets of alternatives, whereas adopting Križ & Spector's (2020) account in this domain requires viewing the question denotation as something more higher order, since candidate denotations are generalized quantifiers.[32] Let us unpack this more, assuming the following lexical entries, now relativized to $\mathscr{H}$.[33]

(28) a. $[\![\text{ate}]\!]^{g,w,\mathscr{H}} = \lambda x.ate_w(\mathscr{H}(i,x))$

b. $[\![?]\!]^{g,w,\mathscr{H}} = \lambda q_{st}\lambda p_{st}.p = q$

c. $[\![\text{which}]\!]^{g,w,\mathscr{H}} = \lambda x_e.\lambda f_{et}.\lambda g_{et}.\ f(x) \wedge g(x)$

It is then possible to assume the following LF in (34a) and the corresponding characteristic function (for a Hamblin set) in (29b), incorporating the reconstruction account outlined in the previous section.

(29) a. [CP λp [wh∃ λx [C' [C ? p] [TP [DP [which x] students] [DIST [VP ate]]]]]]

b. $[\![\text{CP}]\!]^{g,w,H} = \lambda p_{s,t}.\exists x[p{=}\lambda w'.students_{w'}(x) \wedge ate_{w'}(\mathscr{H}(i,x))]$

If the relevant domain is $D = {}^*\{a,b,c\}$, then the result is the set of alternatives displayed in (30).

(30) $\{\lambda w'.ate_{w'}(\mathscr{H}(i,a\oplus b\oplus c)),\ \lambda w'.ate_{w'}(\mathscr{H}(i,a\oplus b)),\ \lambda w'.ate_{w'}(\mathscr{H}(i,b\oplus c)),\ \lambda w'.ate_{w'}(\mathscr{H}(i,a\oplus c)),\ \lambda w'.ate_{w'}(\mathscr{H}(i,a)),\ \lambda w'.ate_{w'}(\mathscr{H}(i,b)),\ \lambda w'.ate_{w'}(\mathscr{H}(i,c))\}$

31 As opposed to in (25), these disjuncts have entailment relations after having been resolved to $\mathscr{H}$.

32 I am indebted to Vincent Rouillard for helping me develop the content in this section.

33 A straightforward extension of their account requires assuming that all lexical entries are relativized to $\mathscr{H}$ with nominal restrictors of determiners being the only exception.

If we take it that in the world of evaluation w, the only students who ate are a and b, then the maximally informative answer is as shown in (31), which due to the presence of the homogeneity parameter has an underspecified meaning.

(31) $\lambda w'.ate_{w'}(\mathscr{H}(i, a \oplus b))$

The answerhood operator must be adjusted to deal with this underspecification. The reformulation is shown in (32). In prose, it requires that a maximally informative true answer constitutes the alternative which is true under all of its candidate interpretations (for all values for the homogeneity parameter $\mathscr{H}$), such that the conjunction of these entails the conjunction of all interpretations of every other alternative, which itself is true on all interpretations.

(32) a. $[\![\text{ANS } Q]\!]^{g,w,\mathscr{H}}$ is defined iff $(\exists! p \in Q)(\forall \mathscr{H}')([\![Q]\!]^{g,w,\mathscr{H}'}(p)(w) = 1 \wedge (\forall q \in Q)((\forall \mathscr{H}')([\![Q]\!]^{g,w,\mathscr{H}'}(q)(w) = 1) \rightarrow [\lambda w'.(\forall \mathscr{H}')([\![Q]\!]^{g,\mathscr{H}'}(p)(w') = 1)] \subseteq [\lambda w'.(\forall \mathscr{H}')([\![Q]\!]^{g,\mathscr{H}'}(q)(w') = 1)]))$

b. When defined, $[\![\text{ANS } Q]\!]^{g,w,\mathscr{H}} = (\iota p \in Q)(\forall \mathscr{H}')([\![Q]\!]^{g,w\mathscr{H}'}(p)(w) = 1 \wedge (\forall q \in Q)((\forall \mathscr{H}')([\![Q]\!]^{g,w,\mathscr{H}'}(q)(w) = 1) \rightarrow [\lambda w'.(\forall \mathscr{H}')([\![Q]\!]^{g,\mathscr{H}'}(p)(w') = 1)] \subseteq [\lambda w'.(\forall \mathscr{H}')([\![Q]\!]^{g,\mathscr{H}'}(q)(w') = 1)]))$

5.2 Embedding under factives

In order to illustrate how the system in Križ & Spector extends to embedded environments, a few more lexical entries must be introduced, as in (33).

(33) a. $[\![\text{know}]\!]^{g,w,\mathscr{H}} = \lambda p.\lambda x.\ K^{w'}_{x,w}\ p(w')$

b. $[\![\text{Anna}]\!]^{g,w,\mathscr{H}} = \text{g}(1)$, where $\text{g}(1) = \mathsf{A}$

Given a sentence embedded under "know" as in (34), the corresponding LF can be seen in (34a) and its resulting set of candidate interpretations is shown in (34b). I will assume that a and b are the sole relevant students that ate lunch in the evaluation world.

(34) Anna knows which students ate lunch.

a. Anna$_1$ knows *ANS* [λp [wh$\exists$ λx [C' [C ? p] [TP [DP [which x] students] [DIST [VP ate lunch]]]]]]

b. $\{\lambda w'.\ K^{w''}_{a,w'}\ ate_{w''}\ (a \oplus b), \lambda w'.\ K^{w''}_{a,w'}\ ate_{w''}\ (a), \lambda w'.\ K^{w''}_{a,w'}\ ate_{w''}\ (b)\}$

Due to the presence of the parameter $\mathscr{H}$, the sentence in (34) is true iff all of its candidate interpretations are true (it is false iff it is false on all candidate interpretations). *Anna knows who ate lunch* is true iff for every cover of the plurality *Cov* such that *Cov* ate lunch, Anna knows *Cov* ate lunch.

5.3 Adding *alles* to the picture

Now it is possible to assemble the pieces and show how *alles*, by virtue of its contribution as a domain restrictor, breaks homogeneity. Homogeneity removal proceeds because the logical relations between the domain alternatives are no longer relevant once *alles* enters the picture. Homogeneity is sensitive to the constitution of the alternative set and *alles* collapses this set to only include those covers for which it holds that there is a member of the cover that contains every member of the plurality. Any proposition resulting from predication of a plurality which is less than a good fit results in presupposition failure. If we suppose that in the evaluation world w, a and b are the only students who ate, it follows that the only alternative which does not suffer from presupposition failure resulting from the LF given in (35a) is the singleton represented in (35b).

(35) Anna knows which students *alles* ate lunch.

a. Anna$_1$ knows *ANS* $[\lambda p$ [wh$\exists$ λx [C' [C ? p] [TP [DP [wh-alles x] students] [DIST [VP ate lunch]]]]]

b. $\{\lambda w'.\, K^{w''}_{a,w'}\ ate_{w''}\ (a \oplus b)\}$

In order to derive the negative sentence given below in (36a), all that needs to be done is negate the set in (35b) as shown below in (36b). Since entailment relations are not preserved, one can see that a follow up stating that Anna knows that (either) a or b ate does not result in a contradiction.[34]

(36) a. Anna weiß nicht, welche Studenten alles zu Mittag gegessen haben.
Anna knows not, which Students *alles* to lunch eaten have.

Anna does not know which students *alles* ate lunch.

b. $\{\lambda w'.\, \neg K^{w''}_{a,w'}\ ate_{w''}\ (a \oplus b)\}$

6 Conclusion

In the first half of this paper, I provided new empirical evidence that the question quantifying particle *alles* is visible to negation and can hence be made at-issue. In the second half, I sketched an account showing that *alles* may be analysed as a domain restrictor. Its homogeneity removing properties and interpretive effects under different embedders provide an avenue for exploring the finer grained properties of plurality in embedded questions.

34 This amounts to the conjunction of all propositions resulting from true candidate interpretations in a given world, disregarding of the value of $\mathscr{H}$. Križ & Spector provide a lexical entry for *all* which does just this. However, on the account presented here, the reconstruction account is crucial to derive the locality facts.

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