

The plural interpretability of German linking elements

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Abstract In this paper, we take a closer theoretical and empirical look at the linking elements in German N1+N2 compounds which are identical to the plural marker of N1 (such as *-er* with umlaut, as in *Häus-er-meer* ‘sea of houses’). Various perspectives on the actual extent of plural interpretability of these pluralic linking elements are expressed in the literature. We aim to clarify this question by empirically examining to what extent there may be a relationship between plural form and meaning which informs in which sorts of compounds pluralic linking elements appear. Specifically, we investigate whether pluralic linking elements occur especially frequently in compounds where a plural meaning of the first constituent is induced either externally (through plural inflection of the entire compound) or internally (through a relation between the constituents such that N2 forces N1 to be conceptually plural, as in the example above). The results of a corpus study using the DECOW16A corpus and a split-100 experiment show that in the internal but not external plural meaning conditions, a pluralic linking element is preferred over a non-pluralic one, though there is considerable inter-speaker variability, and limitations imposed by other constraints on linking element distribution also play a role. However, we show the overall tendency that German language users do use pluralic linking elements as cues to the plural interpretation of N1+N2 compounds. Our interpretation does not reference a specific morphological framework. Instead, we view our data as strengthening the general approach of probabilistic morphology.

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1 Linking elements in probabilistic morphology

In this paper, we examine so-called *linking elements* in German nominal compounds. Linking elements are optional segmental material inserted between the first and second nominal constituents of a compound, such as *-er* in *Liedertext* ‘lyrics’, literally ‘song text’. Linking elements are not obligatory, and many compounds are acceptable with or without them. For instance, the variant *Liedtext* with zero linking element also exists, though speakers may have individual preferences for compounds with or without linking elements (as we will discuss further below). The distribution of the relatively large number of linking elements has previously been described in terms of constraints (some of them soft, others firmly categorical) from different angles (e.g., Fuhrhop 1996; Wegener 2003; Schlücker 2012; Nübling and Szczepaniak 2013; Fuhrhop and Kürschner 2015). Conceptually complete models of linking element selection have been proposed in rule-based systems (possibly with a similarity-based component; see Dressler et al. 2001) and entirely exemplar-based models (Krott et al. 2007).

It is often assumed that linking elements have neither a grammatical function nor a semantic interpretation. In this paper, we question this perspective and look more closely at the possibility that certain linking elements could have a plural interpretation. Interestingly, except for several very rare linking elements, a default zero linking element, and the linking element *-(e)s*, all linking elements are formally identical to the first constituent’s plural marker. Additionally, many first constituents alternate between such a pluralic linking element and another non-pluralic linking element (typically zero or *-(e)s*). This raises the question of whether speaker-hearers or writer-readers (or both) may associate a plural meaning with such pluralic linking elements. So far, researchers have been skeptical toward or even dismissive of this possibility, and in a perception experiment, Koester et al. (2004) could not find evidence that a plural interpretation of linking elements is triggered in spoken German. However, for (written) Dutch linking elements, such effects have been demonstrated repeatedly (Schreuder et al. 1998; Banga et al. 2012, 2013a,b). In this paper, we present systematic research in the form of corpus data and the results of an experiment using the split-100 paradigm which shows that German linking elements are indeed used as cues for the plural meaning of the first constituent in written German compounds.

Findings like this have, in our view, an impact on morphological theory in general for two closely related reasons. First, any morphological framework or theory must be flexible enough to be able to account for phenomena which have been demonstrated to exist—in our case, the systematic occurrence of inflected forms within products of word-formation such as compounds. Classical generative frameworks (e.g., Siegel 1979; Mohanan 1986; Anderson 1992; Pinker 1999) tended to implement strong universal tendencies as hard constraints into the architecture of the framework, which, in our view, does not allow the required flexibility. One example is Siegel’s strict

layering hypothesis, which states that inflection applies derivationally after word formation and that consequently, markers of inflectional categories can only be positioned at the edges of words (as we will discuss further in Sect. 2.2.2). Such approaches have been criticised for many decades, since, as Haspelmath (2010, 391) puts it, “most empirical universals are tendencies”. Pollard (1996) astutely criticises the absurdity of needlessly restrictive generative frameworks in syntax, and Haspelmath (2010) goes even further by suggesting that frameworks should be abandoned altogether, demonstrating with many examples how frameworks sacrifice explanatory adequacy for hard-wired allegedly universal restrictions. With respect to inflection inside German compounds, we provide a framework-free but differentiated image to be summarised in Sect. 6.

Second, findings such as ours lend support to a probabilistic view of morphology and grammar in general. The amount of evidence for the inherent gradedness of grammar has been growing for decades. Hay and Baayen (2005) summarised an impressive number of studies about this topic as it concerns morphology, and Bresnan (2007) and subsequent work have radically changed the way empirical research is conducted in syntax. Even the relevance for linking elements has not gone unmentioned; Arndt-Lappe et al. (2016, 105) include the selection of linking elements in their list of “semi-systematic and gradient properties” of compounds. These properties have been actively researched in recent years, and Arndt-Lappe et al. (2016) stress the important role played by empirical work in this area of investigation. The present study contributes to this body of work by showing that there is a—by no means categorical—tendency for linking elements which take the form of a plural to be interpreted as plurals. Arndt-Lappe et al. (2016, 107) address precisely this issue when they state that “although there is not and probably never has been a one-to-one correspondence between the form and meaning of compounds, the form does provide a wide variety of information to which humans have access in reaching an interpretation”. As we will argue in Sect. 6, it would even be surprising if writer-readers did not pick up on the possibility of using plural forms to denote plural where it makes perfect sense, at least in the absence of strong inhibitory factors.

The paper is structured as follows. In Sect. 2, we review the form and distribution of linking elements in German, and we discuss positions about their potential plural interpretation from the literature. This includes a discussion of a long tradition of research on Dutch linking elements and their plural interpretability. The section closes with an outline of our hypotheses concerning when there might be a preference for pluralic linking elements in compounds, for instance when the internal conceptual structure of the compound enforces a plural interpretation of the first constituent. Section 3 describes a database we created based on the DECOW16A web corpus to investigate these hypotheses. The database shows the frequencies with which a large number of nouns occurring as first constituents in compounds take pluralic and non-pluralic linking elements. It also quantifies the productivity of each of these nouns with these linking elements. In Sect. 4, we use the database to select a large number of first constituents which exhibit linking element alternation (in other words, first constituents which occur reliably with both pluralic and non-pluralic linking elements) and show, using a manually annotated corpus sample of approximately 10,000 compounds containing these first constituents, that pluralic linking elements

are indeed cues for semantic plurality. In Sect. 5, we report an experiment in the split-100 paradigm which corroborates our findings from the corpus study. Finally, in Sect. 6, we discuss the findings in the larger context of probabilistic morphology.

2 Linking elements in German

2.1 The form and distribution of linking elements in German

2.1.1 German linking elements

In this paper, we exclusively deal with determinative (endocentric) nominal compounds, i.e., compounds formed through the concatenation of two constituent nouns (possibly with intervening linking elements) where the second noun (N2) is the head modified by the first noun (N1). While compounding is a recursive process in principle, we ignore complications involved with more complex structures and look only at binary compounds. We refer to these structures as *N1+N2 compounds*.

In the majority of such compounds in German, N1 and N2 are simply concatenated, and N1 appears in its base (uninflected) form, which is identical to at least the nominative singular form. A linking element, as mentioned above, is (in its typical form) segmental material inserted between N1 and N2. Linking elements in compounds are not exclusive to German; see Schreuder et al. (1998), Banga et al. (2013a,b) on Dutch linking elements and see also Krott et al. (2007, 27) for a typological overview of some systems of compound infixoids. However, German speakers use an unusually high number of different linking elements, and they may also make other types of changes to the base form of N1. The list of segmental linking elements is widely accepted to be: *e*, *er*, *s*, *es*, *n*, *en*, *ns*, and *ens* (see Neef 2015, 31; Krott et al. 2007). The elements *e* and *er* can occur together with an optional umlaut on N1, and some compounds only have umlaut on N1 and no segmental linking element at all. Also, certain linking elements can replace N1-final segments. Lastly, N1s ending in schwa (graphemically <*e*>) can drop this schwa in compounds. Even though these are, strictly speaking, not all cases of additional material being inserted into the compound, we will maintain the conventions from the literature and use the term “linking element” as an umbrella term to refer to any formal changes to N1 which occur in the compounding process. Where the distinction is relevant, we will use more specific terminology (i.e., segmental linking elements, umlaut, replacement, deletion).

Before we continue, a few notes on the notation we use in this paper: We will not mark zero linking elements as, for example, \emptyset , but rather represent the simply concatenated compounds as *N1+N2* without anything in between. We will represent a segmental linking element *X* attaching to N1 as *-X*, and *=X* will denote a segmental linking element attaching to N1 with additional umlaut in N1. An umlaut-only linking element is indicated by *=* alone. The special notation **e* is used for deletion of the final schwa of N1. Furthermore, *+* separates N1 (possibly with linking element) and N2 in our analyses. Graphemically, however, German compounds are usually spelled

Table 1 Overview of the different linking elements in German nominal compounds; = is used to denote linking elements which trigger umlaut on N1, *e denotes linking elements where the final schwa of N1 is deleted; the column labelled $\equiv P$ indicates whether the linking element is formally identical to the plural of some declension class of N1

Element	$\equiv P$	Example	Literal gloss	Translation
∅		<i>Haus+tür</i>	house door	'front door'
-s		<i>Anfang-s+zeit</i>	beginning time	'initial period'
-n	✓	<i>Katze-n+pfote</i>	cat paw	'cat's paw'
-en	✓	<i>Frau-en+stimme</i>	woman voice	'female voice'
*e		<i>Kirsch*kuchen</i>	cherry cake	'cherry cake'
-e	✓	<i>Geschenk-e+laden</i>	gift store	'gift store'
$\equiv e$	✓	<i>Händ=e+druck</i>	hand press	'handshake'
=	✓	<i>Mütter=+zentrum</i>	mother centre	'centre for mothers'
-er	✓	<i>Kind-er+buch</i>	child book	'children's book'
$\equiv er$	✓	<i>Büch=er+regal</i>	book shelf	'bookshelf'
-ns		<i>Name-ns+schutz</i>	name protection	'name protection'
-ens		<i>Herz-ens+angelegenheit</i>	heart matter	'affair of the heart'

as one word; the segmentation is intended purely as a reading aid.¹ Table 1 illustrates the different types of linking elements in German in N+N compounds.²

Whether *-en* and *-n* or *-ens* and *-ns* should be described as allomorphic variants (i.e., *-(e)n* and *-(e)ns*) is debated. See Sects. 3.2 and 3.6 of Nübling and Szczepaniak (2013) for an argument in favour of this view and Neef (2015, 33–36) for an argument against it. This issue does not affect our study, and we separate the two potential allomorphs in order to maximise the informativity of our results. Since we do not look at linking elements with *-s* and *-es* in detail, however, we have conflated these two into *-(e)s*. This should not be equated with referring to the linking elements as allomorphs, which they are not, although the genitive suffixes from which they developed are (Szczepaniak 2016; Nübling and Szczepaniak 2013, 81). This was done simply for ease of exposition, since *-es* cannot be a plural suffix and, although *-s* can be, it is avoided within compounds after N1s that take *-s* as their plural suffix (cf. Wegener 2003, 2005; Nübling and Szczepaniak 2013).

¹Some compounds, for example those involving names or loan words, are sometimes written with a hyphen, such as *Adenauer-Zeit* 'Adenauer period'. We exclude them from our study because they virtually never occur with linking elements and have specific compound-internal semantics. There are also occasional spellings of compounds as two words such as *Blumen Welt* 'world of flowers' and with in-word capital letters such as *BlumenWelt*, which are much debated from a normative perspective (see also Scherer 2012). These spellings are assumed to be specific to certain genres (such as adverts) and are quite rare overall. Therefore, we do not include them in our study.

²Linking elements are also found in other sorts of German compounds, for example N+A compounds such as *herzensgut* (*Herz-ens+gut*) 'kindhearted', *lebensfreundlich* (*Leben-s+freundlich*) 'life-sustaining/livable', or *hundelieb* (*Hund-e+lieb*) 'dog-loving'. While their distribution, function, and interpretation in such compounds might be related to that in N1+N2 compounds, our studies reported in Sects. 4 and 5 make use of diagnostic features exclusive to N1+N2 compounds, and we therefore excluded all other types of compounds.

The different linking elements have quite different frequencies, with the zero and *-(e)s* linking elements being by far the most frequent ones. For example, Gallmann (1998, 177) reports that 70% of all N1+N2 compounds have the zero linking element (not specifying whether he refers to type or token frequency). Krott et al. (2007, 29) report that the compound types with the zero linking element make up 65% of all compounds in the CELEX database.

Finally, it should be mentioned that in some terminologies, linking elements would not be called linking elements when they are actual plural markers (i.e., when plural form of the linking element and plural meaning of N1 occur together; Dressler 1987). We follow the liberal choice of words by Banga et al. (2013b), who also call the respective affixes “linking elements” regardless of whether or not they mark plural meaning (see Banga et al. 2013b, 196 for a discussion of stricter views).

2.1.2 Conditions on linking element selection in German

The choice of linking element in any given compound is not fully predictable, but the grammatical gender of N1, its declension class (dependent largely on gender), its phonotactics, and possibly plural semantics all limit the options significantly (see Fuhrhop 1996; Nübling and Szczepaniak 2013). All these morpho-phonological and lexical factors which partially determine the choice of linking element are based on N1, so the distribution of linking elements in general is unanimously treated as suffixation of N1.

Several (soft) descriptive generalisations concerning linking element distribution can be made (cf. e.g. Fuhrhop 1996 and Nübling and Szczepaniak 2013 for extensive overviews). Derived nouns ending in suffixes like *-ung*, *-heit*, *-tum*, etc. have a strong tendency to occur with an *-s* linking element, as in *Heizung-s+wartung* ‘heating maintenance’. Simplex masculine and neuter nouns are those which often take the *-(e)s* linking element, in which case the form is identical to the genitive singular, for example *Boot-s+fahrt* ‘boat trip’ (with neuter *Boot*) or *Tag-es+form* ‘form of the day’ (with masculine *Tag*). Also, N1s ending in full (non-reduced or tense) vowels such as *Oma* ‘grandma’ or *Auto* ‘car’ can never take the *-s* linking element (although *-s* is their only inflectional suffix when they are used as independent nouns) and occur with a zero linking element as in *Auto+wäsche* ‘car wash’.³ Furthermore, feminine nouns ending in schwa virtually always occur with the linking element *-n* (Libben et al. 2002, 32), which is also their plural morpheme. So-called weak masculine nouns and so-called mixed masculine and neuter nouns, which have an *-(e)n* plural, often occur with an *-(e)n* linking element, e.g., *Linguist-en+witz* ‘linguist’s joke/joke about linguists’ and *Schwede-n+humor* ‘Swede humor’.⁴ Finally, *-ens* and *-ns* are idiosyncratic and rare, used only with a handful of N1s.

³See Wegener (2003, 2005) and Fuhrhop and Kürschner (2015) for further discussion of the *-s* linking element and Fehring (2009) for an investigation of an emerging use of *-s* to mark plurality of N1 in northern German dialects.

⁴For weak nouns, the *-(e)n* linking element is also identical to all non-nominative-singular forms, because they follow an otherwise unusual paradigm where the nominative singular is unmarked and all other forms are marked identically with *-(e)n* (see Köpcke 1995; Schäfer 2016).

More systematically, Dressler et al. (2001) showed in a cloze test that the choices German native speakers make with respect to linking elements in novel compounds are partially predictable from rules, but that an analogical component (similarity to existing compounds with the same first constituent) is required. The approach in Krott et al. (2007) shows how a model with very high explanatory power can be constructed completely without rules or exceptions, based only on analogy. Using an implemented exemplar-based model, experimental validation, and post-hoc analysis, they find that the choice of linking elements in novel compounds can be predicted well by considering exemplar families of compounds that have the same N1 together with features of the first constituent such as rime, gender, and inflectional class (Krott et al. 2007, 47).

In sum, the zero linking element can be considered a sort of default, since it is the most frequent form of linking element in N1+N2 compounds and no compound is phonologically unacceptable with the zero linking element. When a linking element does appear, which form it takes is affected primarily by N1. N1s have certain preferences for linking element selection, and they also often disprefer particular linking elements (partially depending on gender, stem-final segments, and the derivational status of N1). There is solid evidence that exemplar effects can account for most selection tendencies. It remains a noteworthy fact, however, that except for the zero and *-(e)s* linking elements, the linking elements which N1s can take are almost always identical to their plural markers.

2.1.3 Alternations between linking elements

Despite the existence of more or less firm constraints on the selection of linking elements, which linking element will be chosen in a given compound is by no means fully pre-determined. Dating back to Augst (1975), alternations between one or more different linking elements with the same N1 have been described. Alternations with more than two alternatives are rare, however. Augst (1975, 134–135) reports that among the 4,025 N1s he examined, 390 occurred with two linking elements, 31 with three, and only eight with four. Notice that the proportion of N1s occurring with two different linking elements is considerable at 9.7%. However, Augst (given the lack of searchable corpora at the time) only analysed forms found in normative dictionaries, which list lexicalised forms and not productively formed compounds. We propose that corpus analysis will likely reveal many more N1s occurring in at least a two-way alternation between a zero linking element and a pluralic linking element.

Some researchers are skeptical towards the idea of productive alternation. Roughly forty years after Augst's study, Neef and Borgwaldt (2012, 31) and Neef (2015, 46) suggest that for each N1, there is only one productive and uniquely determined linking element. They treat all cases of alternation as lexicalised "exceptions".

When faced with an apparent counterexample—the N1 *Ohr* 'ear', which Neef and Borgwaldt (2012, 42) found to occur in the normative spelling dictionary *Duden* (Dudenredaktion 2006) in 19 compound types with a pluralic linking element (*Ohr-en*) and in 15 with no linking element—they conclude not that these forms alternate, but that "the method does not result in a clear picture about the productive form of the first constituent" and that there might simply be a "a developing allomorphy of

the first constituent for this particular lexeme”.⁵ Although the authors refer to their approach as a “corpus study”, most corpus linguists nowadays would very likely reserve the term “corpus study” for work using naturally produced linguistic data. Dictionaries do not reflect productive language use (especially with highly productive phenomena such as compounding in German) but list lexicalised words by definition. We present a corpus study in the more widely accepted sense in Sect. 3.

2.2 Linking elements as plural markers

2.2.1 Plural interpretation of pluralic linking elements in German and Dutch

Our study focusses on N1s which alternate between a pluralic and a non-pluralic linking element, and it is our goal to show that these linking elements actually have a plural interpretation and to clarify when this appears. If they do have a plural interpretation, then at least in some compounds, the linking element is a case of plural inflection inside a compound. We now review some of the research on a potential plural interpretation of pluralic linking elements. We will first consider theoretical and empirical approaches to this question for German compounds, followed by the more advanced research on this question that has been conducted for Dutch.

An extreme theoretical position with respect to any functional or semantic interpretation of linking elements is espoused by Neef and Borgwaldt (2012) and Neef (2015). In these papers, the authors state that linking elements cannot be functional, since no one proposed function (for instance, to provide a conceptual boundary between constituents, cf. Fuhrhop 1996, 530; to close an open syllable ending on schwa, cf. Wegener 2003, 446; to ease articulation, cf. Wegener 2005, 177; or to act as a plural marker when N1 is conceptually plural, cf. Fuhrhop 1996, 534, Wegener 2003, 427) holds strictly for all linking elements across the board. The plural marking function is not strict insofar as a pluralic linking element is not required for N1 to be interpreted as a semantic plural, and a pluralic linking element also does not reliably exclude a singular interpretation. While this in no way excludes the possibility that a pluralic linking element is a soft cue for plurality, the authors seem to suggest that function/meaning and form have to stand in a one-to-one relationship, except for a small number of exceptions which have been lexicalised (e.g., Neef and Borgwaldt 2012, 42). They dismiss polyfunctional explanations altogether, because no stringent system of functions has been proposed which explains exactly under which conditions which linking element is chosen (e.g., Neef and Borgwaldt 2012, 27–29). Such a view (similar to the dual-route approach as discussed in the context of linking elements in Krott et al. 2007) has become less and less tenable in the face of recent research on the nature of the form—meaning relationship in morphology, which paints a clearly probabilistic picture where more often than not, similarity relations play a major role (see Arndt-Lappe et al. 2016, 107). The present study adds to the evidence that such categorical approaches are inadequate with regard to the interpretation of German linking elements.

⁵“Damit liefert die vorgeschlagene Methodik kein klares Bild zur produktiven Vordergliedsstammform. Denkbar ist allerdings, dass sich für dieses spezielle Lexem eine Allomorphie auf der Ebene der Vordergliedsstammform herausgebildet [...]” (Neef and Borgwaldt 2012, 31).

Theoretical approaches to the question of the possibility of inflection within compound boundaries also display conflicting perspectives. For instance, Schlücker (2012, 9) states that there can be no inflection on non-heads in compounds, because these non-heads either do not inflect at all or the suffixes with which they occur (i.e., linking elements) are non-inflectional by definition. This perspective depends greatly on one's analysis of the characteristics of linking elements and on which type of inflection one considers. While it is true that, for instance, linking elements no longer represent genitive case inflection like they originally did, we will show that linking elements should not be considered non-inflectional as concerns number. This more liberal distinction is made by other scholars as well. Fuhrhop and Kürschner (2015, 577), for example, state in their survey of linking elements in Germanic languages that "the expression of number by linking elements generally seems possible", while case marking is mostly considered to be unavailable within compounds. Furthermore, Gallmann (1998, 178–180) distinguishes internally licensed and externally licensed inflectional features. According to him, externally licensed inflectional features are those which are determined by the syntagmatic context in which a noun occurs, such as case assignment by verbs. Internally licensed features, on the other hand, are those which are assigned not by context, but by categorial membership (such as grammatical gender) or interpretation (such as plurality). Gallmann maintains that externally licensed inflectional features—prominently, case—cannot be assigned to non-heads in compounds (N1s), but he does not explicitly exclude internally licensed features like plural marking on N1s. Thus, the possibility of plural marking within German compounds remains theoretically open.

Interestingly, however, it was shown in Koester et al. (2004) that in the perception of spoken German compounds, hearers do not use linking elements with plural form as cues to plural semantics. While this is a substantial finding in support of the impossibility of pluralic linking elements, the picture may very well be different for written German (much like Schreuder et al. 1998 argue for effects of plural semantics in written Dutch compounds).

These examples, though far from all comments made on this topic, illustrate the divide among linguists and grammarians of German. In spite of this, astonishingly little empirical research has been published on the question. However, for Dutch, there exists a decades-long tradition of substantive experimental research into plural interpretations of pluralic linking elements. Schreuder et al. (1998) and Banga et al. (2012) demonstrate how a change in the official Dutch orthography, which assimilated the linking element to the plural marker graphemically, fostered the plural interpretation of non-heads of compounds in written Dutch. Also, Banga et al. (2013a) show that a plural interpretation of N1s in novel Dutch compounds is positively linked to the occurrence of the optional linking element *-en*, which is homophonous with the plural marker. First, they show that subjects prefer to use *-en* with N1 in contexts where a plural meaning of N1 was made clear. Second, they demonstrate that the preference for the pluralic linking element is even activated when the compound contains a singular form of N1 but when it is given a plural meaning by the context, which is evidence that the connection between the linking element and plurality is not just based on a formal recency effect. They confirm that plural interpretation indeed creates a preference for using *-en*, but that form-based repetition effects strengthen the meaning-based effect (Banga et al. 2013a, 45).

Third and of special relevance to our study, they also test German L2 learners of Dutch and find that for them, the plural effect is weaker than for native speakers of Dutch. They offer several possible interpretations for this (Banga et al. 2013a, 45–47). Citing Libben et al. (2002), who show that linking elements in German come with a processing overhead, they speculate that German speakers might have a tendency to avoid linking elements. Also, they propose that since German plurals are not always marked (there is a zero plural in German, just as there is a zero linking element), German speakers might associate linking elements less strongly with plurality. Finally, they argue that plural markers in German are sometimes formally identical to case markers, which could also weaken the connection German speakers establish between plurality and linking elements. We return to these ideas in Sect. 6 after having presented our own results.

In Banga et al. (2013b), the authors compare the interpretation of Dutch compounds by native speakers of Dutch to the interpretation of conceptually identical English compounds by English native speakers. They compare plurality ratings for conceptually plural N1s, i.e., those where a plural meaning of N1 is a de-facto necessity, to plurality ratings for conceptual non-plurals. Their examples include *bananenschil* ‘banana peel’ for a conceptual non-plural and *aardbeienjam* ‘strawberry jam’ for a conceptual plural. In essence, they show that Dutch speakers produce higher plurality ratings for compounds with *-en* and lower plurality ratings for compounds without *-en* for both groups of compounds (conceptually plural and non-plural) compared to English native speakers for the English compounds identical in meaning and structure. That is, the linking element provides Dutch speakers with an additional cue for plurality, independent of the cues coming from the conceptual structure of the compound. In a second experiment, they show that Dutch subjects as L2 speakers of English react to English compounds by and large like English speakers (for a report of some complications, see Banga et al. 2013b, 211). This corroborates findings that the actual presence of the linking element is a key cue for plural interpretation for Dutch speakers.

2.2.2 Consequences of plural linking elements for morphological theories

A crucial point in the discussion of inflection within compounds is whether frameworks and theories can deal with it appropriately, as we mentioned above. In theories ranging from the strict layering hypothesis by Siegel (1979) through the Lexical Phonology of Mohanan (1986) and the A-Morphous Morphology by Anderson (1992) to the words-and-rules theory by Pinker (1999), it has been maintained that inflection applies after derivational word formation (including compounding), leading to inflectional affixes being positioned farther toward the edges of words than derivational affixes and to inflectional affixes not occurring between constituents of compounds. This was encoded in the respective theories as hard and putatively universal constraints. Such approaches were disputed, however, from very early on, for example in Bochner (1984), where the author shows how inflection can occur within derivation (see Kirchner and Nicoladis 2009, 2–3 for more on this debate). Most pertinent in the context of our study is the argument in Banga et al. (2013a, 47–48) that such restrictive theories fail to explain how the Dutch linking element *-en* can have a plural interpretation (thus being an inflectional suffix) and occur between constituents of compounds (see their results summarised above). The same would be

true for German compounds if pluralic linking elements turn out to be plural markers systematically.

However, as Kirchner and Nicoladis (2009, 5) correctly point out, strong tendencies (falsely interpreted as universal constraints in older generative morphology) for inflection to appear only at the edges of words should still be explained. Given this goal, we consider it highly instrumental to describe exactly where and when inflection does *not* appear at the edges of words, and this paper is about such a case. As we have argued in Sect. 1, frameworks should not impose unnecessary restrictions which stand in the way of describing phenomena as they actually occur. Furthermore, the inherent probabilistic nature of linguistic phenomena—most obvious in situations where more than one option is available in a so-called *alternation*—means that investigating preferences might be more useful than searching for strict rules and lexicalised exceptions.

2.3 Outline of our study

Our main hypothesis under investigation is whether a pluralic linking element in a N1+N2 compound is systematically associated with a semantic plural by native speakers of German. We use the term “systematic” in the sense of probabilistic grammar, where preferences (under specific given conditions) are not assumed to be binary but probabilistic, weighted, and better described as numerical rather than discrete. As sources of data, we will use a large corpus and an experimental setup. Since annotating corpus exemplars reliably for whether the N1 in a compound has a plural meaning is quite difficult in the general case, we isolate two specific and relatively easy-to-detect configurations in which a pluralic linking element might signal plurality, where the second configuration (internal plural) is the one we consider to be the crucial one in showing that pluralic linking elements are associated with plural meaning:

1. A plural on the entire compound (formally on the head constituent) might trigger the use of a pluralic linking element. We call this the *external plural effect*.
2. Certain semantic classes of N2s standing in an appropriate semantic relation with N1 might force N1 to have a plural interpretation and therefore lead to a preference for using the pluralic linking element. We call this the *internal plural effect*.

The external plural effect on linking element selection might have two different motivations. First, there are cases where the referents of N1 necessarily form a set or sum entity with more than one member when the compound as a whole is a plural. This might lead to a preference of pluralic linking elements. For example, we might see a preference for a compound *Hund+herz* ‘dog’s heart’ with the non-pluralic linking element (zero in this case) in the singular but *Hund-e+herzen* ‘dogs’ hearts’ with the pluralic linking element (*-e* in this case) in the plural. It is not necessary to distinguish between different non-pluralic linking elements (mainly zero and *-(e)s*). This effect depends to a large extent on the semantics of both constituents and the compound. In the case of *Hundherz*, the effect is clear because each dog has exactly one heart, so multiple dogs entail multiple hearts. With other compounds, such as *Brot+mahlzeit* or *Brot-e+mahlzeit* ‘bread meal’, the picture is blurrier because a single loaf or piece of bread can make several meals, and more than one piece or loaf of

bread can be consumed in one meal. Making matters worse, it could be the generic or mass noun meaning of *Brot* which is addressed, in which case plurality does not even make sense. Since we found that in a majority of the cases, these ambiguities cannot be resolved and the sentences are compatible with both interpretations, we treat the external plural effect on a strictly formal level.

The second potential motivation for the external plural effect is a purely formal one; there might simply be plural agreement within the compound. Banga et al. (2013a) and Banga et al. (2013b) have found that there are effects related to the mere presence of a formal plural of N1 in the context of the compound. However, the plural on the whole compound might trigger a preference for a pluralic linking element on N1, even if the semantic motivation for the external plural effect does not apply. Thus, even if we find evidence for an external plural effect, we could not be sure that it is an effect related to plural meaning.

The internal plural effect, on the other hand, is only related to the lexical meanings of the compound's constituents, and it is similar to the conceptual plurals in Banga et al. (2013b), as discussed above. Prominently, N2s that provoke this effect might have a collective meaning. In this case, regardless of the grammatical number of the whole compound, there are necessarily several referents of N1 involved conceptually. Examples include true collectives like *Kindergruppe* 'group of children', metaphorical collectives as in *Zitateregen* 'rain of quotations', reciprocals such as *Räderwechsel* 'swapping of tyres', or relational N2s as in *Lochdistanz* 'distance between (the) holes'.

The external plural condition is weaker both conceptually and in terms of operationalisation, so if pluralic linking elements are indeed interpretable as plural markers, we expect to find an effect especially for the internal plural condition. Interestingly, if we find evidence only for the internal plural effect but not the external plural effect, this would fit within a probabilistic version of previous findings that plurality in compounds is purely conceptual or inherent to N1 and does not depend on the grammatical context of the compound (see discussion above, for example Gallmann 1998).

In Sect. 4, we study these two specific hypotheses using corpus data. Then, in Sect. 5, we examine them in an experimental paradigm (split-100 ratings). Before we turn to these studies, Sect. 3 describes the exploratory work that allowed us to make an informed selection of items for the studies. It also shows that there is a significant number of N1s alternating between pluralic and non-pluralic linking elements, contrary to assumptions made by some researchers such as Neef and Borgwaldt (2012), Neef (2015).

3 Data

3.1 Corpus choice

We chose the web-crawled DECOW16A corpus (Schäfer and Bildhauer 2012; Schäfer and Bildhauer, *in preparation*) for all our corpus work.⁶ This corpus was

⁶See <http://corporafromtheweb.org/> for project information and <https://www.webcorpora.org/> for access to the corpora. The corpus is available free of charge to anyone working in academia. The same is also

the obvious choice for several reasons. First of all, it is available in an on-line query interface but also for scripted access and (in sentence-wise shuffled form) for download. The large-scale productivity assessment to be reported in Sect. 3.2 would not have been possible without scripted access. More importantly, using large amounts of recently produced data, including data not written under strong normative pressure (such as text from forums and other community websites) is in our view ideal for research on productive processes from a synchronic perspective (be it descriptive, geared towards competence grammar, or cognitively oriented). The only other very large available corpus containing recent German would be the *Deutsches Referenzkorpus* (DeReKo) by the *Institut für Deutsche Sprache* (Kupietz et al. 2010), but (at least currently) it is not available for scripted access, and it mostly contains newspaper text. Finally, the COW corpora are based on an improved methodology also used to build the WaCky corpora (Baroni et al. 2009), and there are other similar web-derived corpora also actively used by many linguists, such as the SketchEngine corpora (Kilgarriff et al. 2014). Web corpora can thus be regarded as an established source of data on par with traditionally compiled corpora.

3.2 Productivity assessment

For the studies reported in Sects. 4 and 5, we had to choose a set of N1s to be examined more thoroughly using corpus data and a set of compounds to be used as the items in the split-100 experiment.⁷ Seven different potentially pluralic linking elements had to be considered (=e, =er, -er, =, -e, -en, -n). In the case of the corpus study, we wanted to select ten N1s occurring with each of those linking elements. For each of the resulting seventy N1s, the design of the study consisted of drawing samples of one hundred occurrences with that pluralic linking element and one hundred occurrences without that linking element. This was to ensure that all linking elements were represented appropriately in the sample, and it limited the maximal expected size of the concordance for manual annotation to 14,000 lines, which is a large but manageable quantity.⁸ For the experiment to be reported in Sect. 5, an even smaller selection of twelve N1s was required (see Sect. 5.1 for the details on why that number was twelve).

However, choosing those relatively few items from the thousands of possible nouns functioning as N1 is not trivial. Most importantly, we had to find nouns which are used productively as N1 both with the pluralic linking element and without it, i.e., which have the capability of forming new compounds with a pluralic or a non-pluralic linking element. Some N1s (like *Kind* ‘child’ or *Huhn* ‘chicken’) do not alternate between those two variants and always occur with the pluralic linking element, either by way of lexical preference or because of phonotactic constraints. In other cases, there is just a very strong preference for or against the pluralic linking element. Therefore,

true for the English ENCOW16A (16.5 billion tokens), the French FRCOW16A (10.8 billion tokens), the Spanish ESCOW16A (7.1 billion tokens), as well as the older Swedish SVCOW14A (8.4 billion tokens) and Dutch NLCOW14A (6.7 billion tokens).

⁷See <https://doi.org/10.5281/zenodo.1323211> for a copy of the full data set and all scripts used in the research presented here.

⁸In Sect. 4.1, we explain why the final sample ended up being slightly smaller.

it was necessary to find those N1s which are used productively with both alternatives and to make an informed choice from among them. Because it is unlikely that enough N1s exist which have exactly the same productivity with a pluralic and a non-pluralic linking element, any sample should be representative of the whole spectrum of productivity. To obtain such a sample, we first used methods of automatic data extraction (with manual quality control) to analyse literally *all* compounds in the DECOW16A corpus. The resulting database informs us about how strongly N1s tend to appear with pluralic linking elements (PLs) and with non-pluralic linking elements (NPLs), and how productively they are used with these linking elements.

We began by extracting all compounds with a nominal head from the DECOW16A web corpus (Schäfer and Bildhauer 2012; Schäfer and Bildhauer, *in preparation*).⁹ In the corpus, nominal compounds come with full structural analyses created automatically using the SMOR finite-state morphological analyser (Schmid et al. 2004) and extensive pre- and post-processing implemented by the COW creators (Schäfer and Bildhauer, *in preparation*). We then went on to extract all N1+N2 compounds and all N1s from that compound database. For each of the PLs, we generated exhaustive lists of the N1s with which it occurs and which have a plural identical to the PL. These lists of N1 candidates were extracted automatically, but they were checked manually to remove the erroneous matches common with methods of automatic extraction.

Then, for each of these N1s we counted its number of compound types, its number of compound tokens, and its number of compound hapax legomena (i.e., those compounds containing it which occur only once in the corpus). Since we are interested in the alternation for each N1 of PLs and NPLs (the latter can manifest themselves as no linking element at all, as deletion, or as a non-pluralic linking element such as *-s*), we also extracted the same counts for the N1s in compounds with a NPL. An overview of the type frequencies (F) and token frequencies (f) of the different linking elements in DECOW16A is given in Table 2. In these counts, mass nouns and weak nouns (which do not have an unambiguous plural marker) were included in order to provide a complete overview. Since they were removed for all further analysis reported below, reported frequencies in later sections might be lower, especially for *-n* and *-en*. Table 2 is important inasmuch as the numbers reported in it are in line with previous reports based on much smaller corpora such as Wellmann et al. (1974), Kürschner (2005), or Krott et al. (2007) (see also Schlücker 2012, 9). This is evidence showing that the automatic methods of data extraction which we used likely did not affect the quality of the results in a serious way.

As pointed out at the beginning of this section, an informed choice of items for the corpus study and the experiment required ensuring that the chosen N1s have the capability of forming new compounds with PL and NPL. Therefore, we calculated measures of productivity for each N1 with PL and NPL. The *potential productivity* is the measure of choice for this as it “gauges the extent to which the market for a category is saturated” (Baayen 2009, 902, see also 906–907). The potential productivity is appropriate for our purposes because some compounds might be lexicalised either with PL or with NPL, and it would not make much sense to try to examine

⁹The resulting database, which contains comprehensive aggregated information about the 22,380,133 compound types accounting for 478,342,305 tokens in the corpus, is made publicly available by the COW project.

Table 2 Type frequencies (F) and token frequencies (f) of all linking elements in N1+N2 compounds in DECOW16A; N1 is the non-head noun in noun-noun compounds

	Compound <i>F</i>	%	Compound <i>f</i>	%	N1 <i>F</i>	%
∅	3,409,883	60.252	194,187,343	61.379	18,515	41.769
-s	1,340,565	23.687	79,131,193	25.012	20,274	45.737
-n	587,365	10.379	25,175,402	7.957	2,343	5.286
-en	170,906	3.020	5,293,805	1.673	1,858	4.192
*e	43,876	0.775	6,744,777	2.132	88	0.199
-e	39,978	0.706	1,560,226	0.493	844	1.904
-er	21,398	0.378	2,109,421	0.667	30	0.068
=er	20,679	0.365	893,547	0.282	50	0.113
=e	12,679	0.224	578,171	0.183	279	0.629
-ns	7,205	0.127	546,419	0.173	16	0.036
=	3,046	0.054	63,591	0.020	28	0.063
-ens	1,807	0.032	90,428	0.029	2	0.005
Σ	5,659,387	100.000	316,374,323	100.000	44,327	100.000

an alternation with N1s which occur mostly in lexicalised compounds. As shown in (1), the potential productivity P^P is simply the number of the hapax legomena f_1 of compounds with $N1_\lambda$ divided by the token frequency f of compounds with $N1_\lambda$, where λ is a variable standing for either PL or NPL.

$$P^P(N1_\lambda) = \frac{f_1(N1_\lambda)}{f(N1_\lambda)} \quad (1)$$

The interpretation of P^P is intuitive, as it is 0 when there are no hapax legomena in the corpus, in which case $f_1(N1_\lambda) = 0$ (no productivity whatsoever). Furthermore, it is 1 if all tokens are hapax legomena, in which case $f_1(N1_\lambda) = f(N1_\lambda)$ (maximal productivity). It can be regarded as a proportion, and its range is therefore [0, 1].

In total, we found 4,393 N1s which occur with both PL and NPL. Figure 1 shows the productivity analyses for all of these N1s, and each dot represents one N1. The dot's position is determined by its P^P value with PL (x-axis) and with NPL (y-axis). Additionally, the larger a dot is, the higher is its type frequency with PL, and the darker it is, the higher is its type frequency with NPL. From the panels for *-n* and *-en*, it is apparent that N1s with all sorts of ratios of high and low productivity with PL and NPL exist. The tendency for dots to be smaller towards the right-hand side (high productivity with PL) and lighter towards to top (higher productivity with NPL) is explained by the fact that a lower overall type frequency makes it is easier to achieve a high productivity score. In the extreme case, an N1 has a type frequency of 1 as an N1, and there is also only one occurrence of it (necessarily a hapax legomenon) as N1, which results in a potential productivity score of 1. Since the *-n* and *-en* plurals (of N1s) are often used when rare loan words appear as N1, there are many items with low type frequency and a high productivity score. Examples include *Ikonostase* (pl. *Ikonostasen*) 'iconostasis', which has an N1 token frequency and an N1 hapax

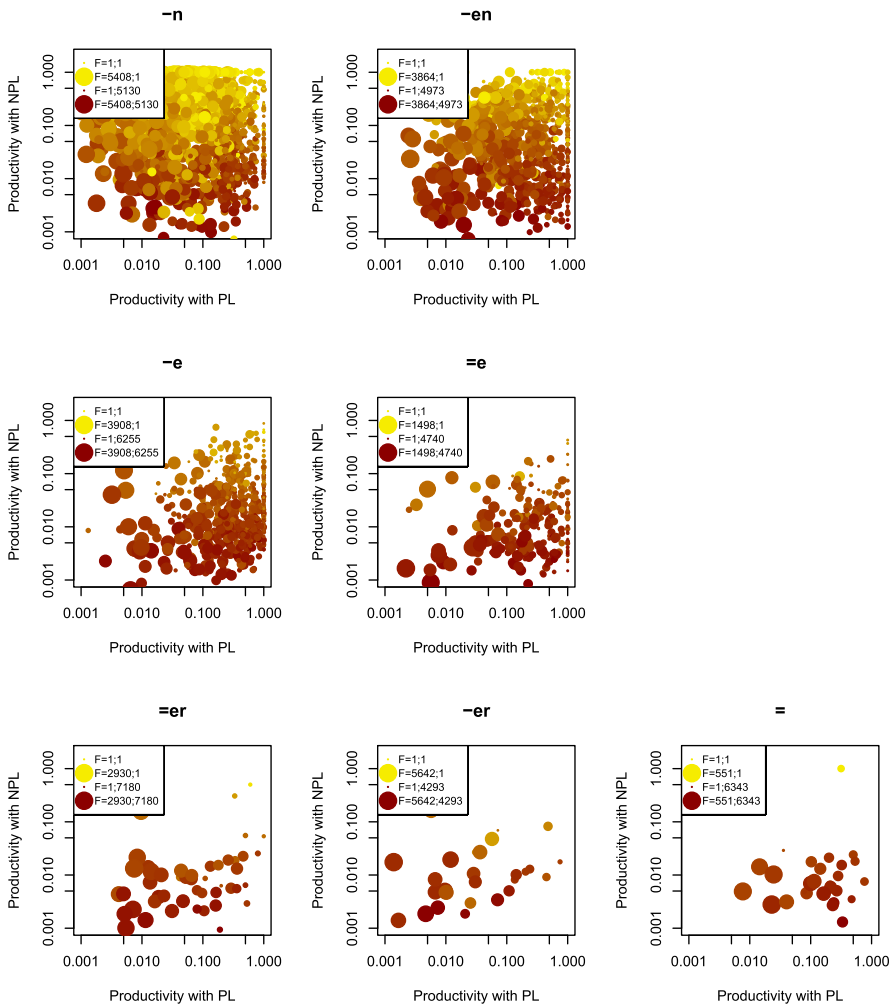


Fig. 1 Comparisons of the potential productivity of N1s (non-heads in noun-noun compounds), grouped by plural linking elements (PLs); colours and sizes encode the type frequencies (F) with PL and NPL (non-plural linking elements); axes are on a logarithmic scale

count of 2 with PL (thus a potential productivity of 1) and *Testator* (pl. *Testatoren*) ‘testator’ with an N1 token frequency and an N1 hapax count of 1 with PL (thus also a potential productivity of 1).

First and foremost, this analysis shows quite impressively that N1s which alternate productively between use with PL and NPL are not rare or idiosyncratic as assumed by some researchers (see Sect. 2). Clear tendencies are observable, however. For N1s with *-e* and *=e*, and even more so for those with *=er*, *-er*, and *=*, the productivity scores with PL are spread out between 0 and 1. However, there are virtually no N1s in these classes which show a particularly high productivity (much higher than 0.1) with NPL. The type frequencies are, however, still quite high for both PL and NPL,

as reflected in the colour and the size of the dots. For *=er*, for example, the 25th and 75th percentiles of the token frequencies with PL are at 16 and 469 types, respectively. With NPL, they are at 482 and 2,190 types. In Sects. 4 and 5, we use the data described here to make informed selections of items for further study and we also detail the studies performed with these items.

4 Corpus study

4.1 Queries

As explained in Sect. 2, we will determine whether two distinct factors increase the probability that N1 in N1+N2 compounds occurs with a PL, given that N1 alternates between a PL and a NPL. The first potential factor is a plural on the whole compound (formally on N2, which is the head). The second factor is whether a semantic relation between N1 and N2 holds which forces N1 to have plural semantics. To this end, we manually annotated corpus exemplars containing N1+N2 compounds for whether they are plurals and whether a plural-enforcing semantic relation holds between N1 and N2. Before turning to this annotation process in Sect. 4.2, the current section describes how we extracted and prepared a concordance for the manual annotation.

First, as explained at the beginning of Sect. 3.2, a selection of N1s was chosen which represents the population of N1s well with regard to their productivity scores with PL and NPL. Furthermore, it was explained that the productivity measures can be misleading in the case of low type frequencies. Therefore, only N1s which had a minimal type frequency of 50 as N1 with PL and NPL were used. In order to exclude nouns which occur with reasonable type frequency in compounds but infrequently as standalone nouns, only N1s with a minimal token frequency outside of compounds were included. To implement this restriction, we used the notion of the *frequency class* (or *frequency band*) of a word (Perkuhn et al. 2012, 80). The frequency class $c(w)$ of a word w increases with the word's token frequency $f(w)$. Calculation of the frequency class additionally relates the token frequency of the word in question to the number of tokens of the most frequent word in the corpus (f^{max}) and accounts for the power law distribution of word frequencies.¹⁰ It is given by (2), where $\lfloor \cdot \rfloor$ denotes the function that rounds down to the next integer.

$$c(w) = \left\lfloor 0.5 - \log_2 \left(\frac{f(w)}{f^{max}} \right) \right\rfloor \quad (2)$$

The most frequent word in DECOW16A, according to the official frequency lists, is *und* 'and' with $f(und) = 258, 507, 195$. Relative to this f^{max} value, we only considered words with a frequency class up to and including 15, a class where, for example, *Lid* 'eyelid' ($f = 10, 746$), *Seilschaft* 'rope team' ($f = 9, 237$), and *Verlies* 'oubliette' ($f = 6, 734$) are found.

¹⁰See Piantados (2014) for a recent overview, including the many problems with actual word frequency distributions.

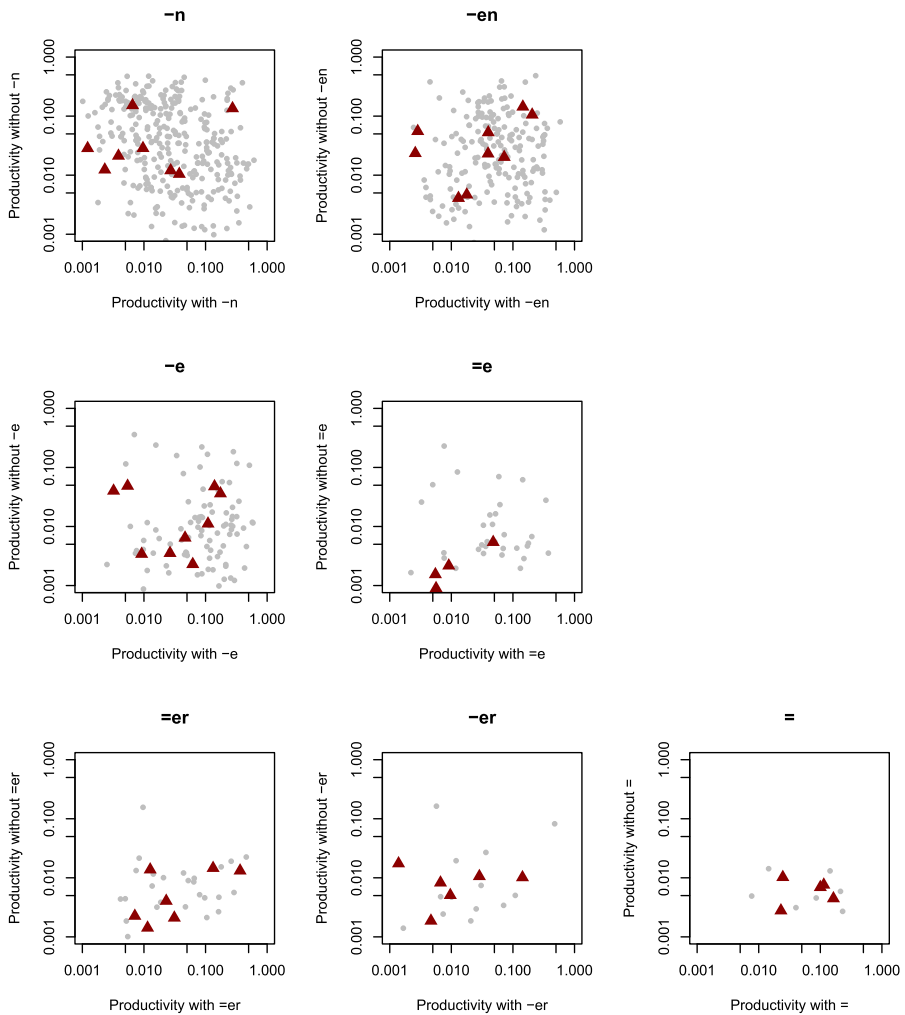


Fig. 2 Selection of the N1s for the corpus study (triangles) in the context of all possible N1 candidates meeting the minimal criteria (dots); the x-axis and y-axis plot the potential productivity of N1 with PL and NPL, respectively (see Fig. 1 for abbreviations); axes are on a logarithmic scale

From the set of N1s which fulfilled the given criteria, we sampled between five and ten nouns per PL. Ideally, we would have had ten per PL, but since some of the PLs occurred with relatively few N1s, there were not always ten nouns available which met our criteria. At the end, we were left with a set of 48 nouns that were countable (i.e., no mass nouns), not collectives, and distributed approximately uniformly across the productivity spectrum as it was visualised in Fig. 1. In Fig. 2, each of the dots represents one N1 which fulfils the frequency-based selection criteria. The triangles mark those which were chosen for the corpus study based on the additional criteria. Overall, the sample represents the spectrum of productivity quite well.

The queries we used to retrieve the compound exemplars containing the 48 chosen N1s were made in DECOW16A. For each N1, we made one query searching for compounds containing it with PL and one otherwise identical query searching for compounds containing it with NPL. We performed deduplication on the compounds inasmuch as we only allowed one instance of each identical compound word form to pass. Otherwise, highly frequent and typically lexicalised compounds would have accounted for the best part of the concordances. However, we did allow different word forms of the same compound in the concordances, in order to get both singular and plural forms. We extracted all exemplars matching the query, making random sub-samples for annotation.

4.2 Annotation

From each of the query results of the 48 N1s described in Sect. 4.1, we annotated one hundred randomly chosen cases with PL and approximately one hundred with NPL. Due to some minor clean-ups in the quality control process, the final sample size is not exactly $n = 9,600$ but $n = 9,414$. Annotating singular and plural was unproblematic, except where singular and plural forms were homographic *and* the context did not help to disambiguate the two. Such cases were discarded and not used for the study.

Determining whether the semantics of N2 and the semantic relation between N1 and N2 forces N1 to have plural semantics was more intricate, and we found several classes of N2s characteristic of this relation. A clear case of plural-inducing N2s are collectives such as *Gruppe* ‘group’ as in *Kind-er+gruppe* or *Kind+gruppe* ‘group of children’ or *Haufen* ‘heap/pile’ as in *Brett-er+haufen* or *Brett+haufen* ‘pile of boards’. Even metaphorical collectives are usually unproblematic, for example *Regen* ‘rain’ in compounds like *Zitat-e+regen* or *Zitat+regen* ‘rain of quotations’. Another clearly discernible group are reciprocals such as *Wechsel* ‘swap/exchange’ as in *Räd=er+wechsel* or *Rad+wechsel*, ‘swapping of tyres’. Furthermore, there are N2s such as *Distanz* ‘distance’ as in *Löch=er+distanz* or *Loch+distanz* ‘distance between (the) holes’, which were annotated as plural-inducing N2s if it became clear from the context that a distance *between* several objects was referenced. Also, compounds with N2s like *System* ‘system’ as in *Element-e+system* or *Element+system* ‘system of elements/periodic system’ were annotated as containing an N1 with a forced plural interpretation if the reading was clearly that of a ‘system of (several) elements’.

In addition to these fairly clear-cut cases, there is a second group of compounds in which the plural-inducing quality of the N2 is strongly dependent on context and world knowledge. Most prominent among these are N2s which denote a container of some sort. Examples include *Äpfel= +lager* or *Apfel+lager* ‘storage for apples’, *Brief-e+katalog* or *Brief+katalog* ‘catalogue of letters’, and *Lied-er+buch* or *Lied+buch* ‘book of songs/songbook’. In theory, the N2s in these compounds *could* denote some sort of container which holds only one object (for instance, it is conceivable—if unlikely—that the storage space for apples could have only one apple in it), but both world knowledge and the particular context in which the compound appears render this sort of interpretation impossible. However, since the interpretation

Table 3 Contingency table for external plural sub-study

	Pl. compound	Sg. compound
NPL	1,574	3,133
PL	1,474	3,234

of this kind of containment compound is context- and world-knowledge-dependent, we will analyse them separately from the clear-cut cases shown above. The presentation of the final sample will show the results for only the first, clear-cut cases under the label of *strict annotation* and the combined results for both the clear-cut and the extended cases under the label of *lax annotation*.¹¹

4.3 Results

As mentioned in Sect. 4.2, the size of the manually annotated sample of 48 N1s was $n = 9,414$. All exemplars were annotated for internal and external plural, and we treat the two annotations as two sub-studies, starting with the external plural sub-study.

There are 6,367 singular compounds and 3,048 plural compounds in the sample. Also, there are 4,708 cases with PL and 4,707 with NPL. The question is whether there is a high enough number of exemplars with PL in a plural compound that we might conclude that there is an external plural effect. The contingency table showing the two variables' bivariate distribution is given in Table 3.

A χ^2 test on the contingency table produces a significant result at $\text{sig} = 0.05$ ($\chi^2 = 4.786$, $df = 1$, $p = 0.029$). However, despite the very large sample size, the p-value is relatively close to 0.05, and the effect size is quite low at $v = 0.023$, which indicates that the effect is probably spurious. To make matters worse, an inspection of the symmetrical (standardised) residuals (2.210 for plural compounds with NPL and singular compounds with PL as well as -2.210 for plural compounds with PL and singular compounds with NPL) shows that the spurious effect even has the wrong direction, i.e., PL is less frequent in plural compounds than expected under the null hypothesis.

Thus, we have found no evidence to support the external plural hypothesis in the global analysis of the data set (which is not the same as finding evidence *against* it). There might be item-specific differences between N1s or groups of N1s which take different PLs. In order to check for this, we calculated one χ^2 test for each N1 with an approximate sample size of $n = 200$ for each test. Since we are testing a family of connected hypotheses, p-values need to be corrected (correction for group-wise error). We used Šidák's method (Šidák 1967), which is slightly less conser-

¹¹We think it is encouraging that Banga et al. (2013b) found the stable and expected results even using a more cavalier operationalisation of what they call conceptual plurals. "These form types could be divided into two conceptual types: the modifier of the compound was either conceptually singular (e.g., *bananenschil* 'banana skin' and *ballonvaart* 'balloon ride') or conceptually plural (e.g., *aardbeienjam* 'strawberry jam' and *appeltaart* 'apple pie')". The problem with *strawberry jam* is that *strawberry* could address the generic meaning ('strawberry type') or a mass noun version ('strawberry substance'), in which case the numerosity of referents of N1 would be much weaker conceptually. We had to assume that there would be more confounding factors in the corpus study than in a controlled experiment. Therefore, to be on the safe side, we did not consider hazy cases like these to be internal plurals.

Table 4 Contingency table for internal plural sub-study; the tuples represent the values for *strict*; *lax* annotation

	Internal pl. relation	No internal pl. relation
NPL	214;271	4,493;4,436
PL	697;966	4,010;3,741

vative than the well-known Bonferroni correction (at least for uncorrelated tests).¹² The low counts in some cells in our data make the χ^2 approximation inexact, so we used a Monte Carlo replacement for the traditional χ^2 test (Hope 1968) as implemented in the standard `chisq.test` function in R (R Core Team 2014). The procedure calculates these marginal sums and then generates random permutations for the contingency table given the marginals. We used $b = 10,000$ permutations. Finally, the effect sizes (v) were calculated and multiplied by the sign of the top left cell of the residual table. This means that, in addition to quantifying the magnitude of the effect size, they also reflect whether, for each N1, the co-occurrence of PL and plural semantics on N1 is preferred (positive sign) or dispreferred (negative sign).

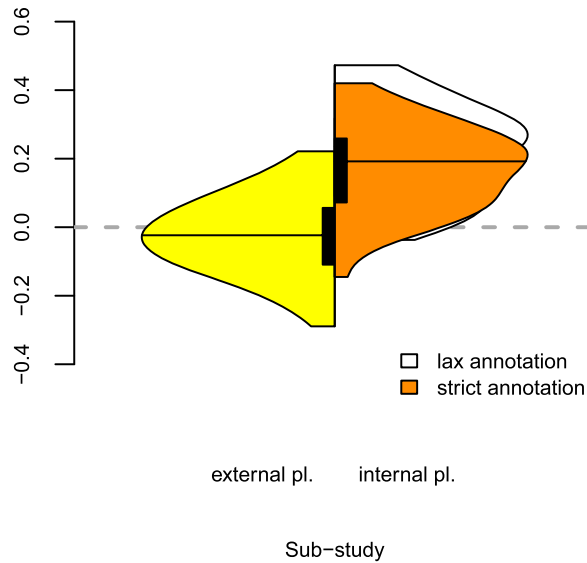
These results confirm those of the global test reported above. Only one test reaches $\text{sig} = 0.05$. The effect sizes are centred around 0 with a mean of $\bar{v} = -0.022$, a median of $\tilde{v} = -0.024$, and a standard deviation of $s(v) = 0.116$. This is expected in a situation where there are no effects.

The picture changes when we move on to the analysis of the internal plural sub-study. Here, we examine whether the occurrence of PL is more frequent in internally plural compounds, i.e., compounds with an N2 that forces plural semantics on the N1. Recall from Sect. 4.2 that we carefully distinguished between clear cases and less clear cases, calling the two annotation schemes *strict* and *lax*. We therefore specify two values separated by a semicolon for the relevant statistics (*strict*; *lax*). The sample contains 911;1,237 cases with an internal plural relation and 8,503;8,177 cases with no internal plural relation. Table 4 shows the contingency table for the two variables PL vs. NPL and internal plural relation vs. no internal plural relation.

A χ^2 test reaches $\text{sig} = 0.05$ ($\chi^2 = 282.343;448.259$, $df = 1; 1$, $p \approx 0; 0$). However, the overall effect size is still not very high at $v = 0.173;0.218$. At least for the *lax* annotation scheme $v \geq 0.2$, making the effect worthy of mention. Individual (per-N1) tests were also calculated with the same parameters as described above for the external plural sub-study. Figure 3 compares the distribution of v values for the external plural sub-study (left) and the internal plural sub-study (right) in the form of a split violin plot. Violin plots are extensions of standard box plots; see Hintze and Nelson (1998). The horizontal line represents the median and the black vertical bar the interquartile range (i.e., the range of the middle 50% of the sample). The additional outer shape represents a kernel density estimate of the sample. For the internal plural sub-study, *strict* and *lax* annotation are both shown. Obviously, the difference

¹²We also tried Holm's and Hochberg's methods, but the differences between all those methods are small enough that they do not lead to different interpretations of the results. Instead of adapting the sig level, we corrected the p -value directly using $p_S = 1 - (1 - p)^m$ where m is the number of tests ($m = 48$ in this case).

Fig. 3 Distribution of signed Cramér's v scores for the internal and external plural data



between the two annotation schemes is not huge, and virtually identical conclusions can be drawn based on either of them. While the external plural has zero average effect, the internal plural has an average effect of roughly 0.2.

Even more informative is a closer look at the individual results. Figure 4 represents for each N1 the signed effect strength in the internal plural sub-study as the dot's location on the horizontal dimension and the p-value through the colour coding. The darker the dot is, the lower the p-value. The colour mapping is logarithmic, such that any dot representing a p-value above $\text{sig} = 0.05$ is already significantly lighter than the darkest colour. The N1s are arranged in groups defined by their PL. The groups are sorted by their mean effect strengths, and within each group N1s are sorted by their effect strengths.

The detailed analysis shows that there are considerable differences between linking elements. N1s with $=e$ and $=er$ especially show good effect strengths in addition to reaching reasonable significance levels. Those with $-er$ and $=$ show mixed results, and for $-e$, $-en$, and $-n$, we find only very weak effects and non-significant p-values, which would normally be dismissed completely. However, even though the results for the last-mentioned PLs are negligible by themselves, it should still be noticed that all N1s show a positive effect except *Ei* 'egg' and *Katze* 'cat', which lean ever so slightly towards the negative side.

If there were no general co-occurrence preference between a PL and an internal plural relation, we would not expect this strong positive trend in the distribution of v scores. Rather, roughly as many negative as positive v scores distributed around 0 would be expected, as was the case in the external plural condition; see Fig. 3. These results thus support the hypothesis that there is a general co-occurrence preference between PL and an internal plural relation.

Finally, it is noteworthy that the order of the PLs in Fig. 4 is the mirror image of their order in Fig. 1 and Fig. 2. The less type-frequent a plural marker is,



Fig. 4 Individual per-N1 effect strengths and Šidák-corrected p-values for the internal plural sub-study; groups (PLs) are sorted by descending overall effect strength (strict); per group, N1s are sorted by descending effect strength (strict)

the more strongly it tends to be interpreted as a plural marker even when used as a linking element. It should be noted that these less type-frequent plural markers are those with an umlaut on N1. We return to these results in our theoretical interpretation in Sect. 6. But first, we report the results of a split-100 experiment in Sect. 5.

5 Split-100 experiment

5.1 Design, choice of items, and participants

This experiment was designed to examine how strongly native speakers of German prefer a PL through two sub-experiments investigating internal and external plural relations. A split-100 task was chosen because it is claimed that participants make subtler judgements compared to a binary forced-choice task (Ford and Bresnan 2013; Verhoeven and Temme 2017). In a split-100 task, subjects are offered two options (here: a compound with PL or NPL) and they can weigh their preference for either of them, assigning integer values between 100;0 (clear preference for option one) and 0;100 (clear preference for option two) to the tuple of options.

The experiment was conducted using PsychoPy (Peirce 2007) and contained two sub-experiments merged into one run for each subject. Subjects made eight decisions pertaining to the internal plural sub-experiment and eight decisions pertaining to the external plural sub-experiment. In addition to these 16 targets, an experiment run contained 41 fillers, which results in a target-to-filler ratio of 1:2.5. A training phase with five sentences/decisions preceded the experiment.

Subjects were presented with sentences containing a blank where a compound should go. The two variants of the compound (with PL and NPL) were shown on the same screen below the sentence with a slider in between, which could be moved freely to assign a preference between 100;0 and 0;100. The corresponding numbers were displayed dynamically as subjects moved the slider. When they were satisfied with their decision, subjects pressed a button to store it and continue on. After each sentence, subjects answered a simple distractor question by pressing one of the digits 1–9. The questions were not related to the sentences and were simple arithmetic or counting exercises. Finally, it should be noted that the order of the items and fillers was randomised for each participant.

The choice of items was guided by the exploratory data analysis described in Sect. 3. First of all, we chose N1s which have roughly equal productivity with PL and NPL. We then tried to find for each N1 some semantically appropriate N2s which clearly trigger internal plural semantics and ones which clearly do not. Finally, we checked the token frequencies of the resulting N1+N2 compounds with PL and NPL in the corpus, because we wanted to use compounds as items which were productively formed for the subjects inasmuch as they had never used or heard/read them before (at least with a high probability). The process turned out to be an iterative one because compounds meeting all desired criteria were difficult to find.

Table 5 presents the results of the selection process. The table shows the potential productivity P^P for the N1 with PL and NPL. These roughly match in many cases, for example $P_{PL}^P(Bad) = 0.013$ and $P_{NPL}^P(Bad) = 0.014$. The frequency classes c of the full compound with PL and NPL is also given, where class 28 corresponds to a token frequency of 1, and no frequency class (–) is assigned to words with a token frequency of 0. Additionally, the total difference in token frequency of the two compounds is specified (Δ_f), where the maximum absolute difference is 63, which is clearly not extreme, given that the corpus contains 21 billion tokens and approximately 15 billion words.

Table 5 Selection of items for split-100 experiment; P_{PL}^p and P_{NPL}^p are the potential productivities of the N1 (non-head in a noun-noun compound) with pluralic linking element (PL) and non-pluralic linking element (NPL), respectively; c_{PL} and c_{NPL} are the frequency bands of the compound with PL and NPL, respectively; Δ_f is the difference in raw token frequency between the compound with PL and NPL

N1	LE	N2	P_{PL}^p	P_{NPL}^p	c_{PL}	c_{NPL}	Δ_f	Gloss
Bad	=er	Kooperation	0.013	0.014	25	28	6	bath cooperation
Bad	=er	Eingang	0.013	0.014	28	23	-27	bathroom door
Weg	-e	Zusammenlegung	0.009	0.003	-	-	0	path merger
Weg	-e	Beschriftung	0.009	0.003	-	26	-3	pathway label
Brett	-er	Bündel	0.029	0.011	28	-	1	board bundle
Brett	-er	Schliff	0.029	0.011	-	28	-1	board cut
Schwert	-er	Abdruck	0.143	0.010	-	28	-1	sword mark
Schwert	-er	Sammlung	0.143	0.010	25	26	5	sword collection
Haus	=er	Abbruch	0.011	0.001	23	22	-52	building demolition
Kraft	=e	Stärke	0.008	0.003	26	23	-20	force strength
Grab	=er	Buchung	0.016	0.003	-	-	0	grave reservation
Punkt	-e	Farbe	0.008	0.004	-	23	-38	dot colour
Blatt	=er	Analyse	0.014	0.007	-	22	-63	leaf analysis
Bett	-en	Länge	0.018	0.005	21	21	-30	bed length
Last	-en	Berechnung	0.010	0.006	22	22	25	load calculation
Hemd	-en	Schlitz	0.072	0.020	28	25	-8	shirt slit

The first eight compounds shown in the table were used as items for the internal plural sub-experiment. The N2s *Kooperation* ‘cooperation’, *Zusammenlegung* ‘merger/unification’, *Bündel* ‘bundle’, and *Sammlung* ‘collection’ are clear triggers of internal plural. In contrast, *Eingang* ‘entry’, *Beschriftung* ‘label(ling)’, *Schliff* ‘cut/sharpening’, as well as *Abdruck* ‘(physical) mark/impression’ cannot trigger internal plural semantics at all. Because the internal plural sub-experiment is sensitive to the specific semantic relation between N1 and N2, it might be sensitive to item-specific effects pertaining to concrete combinations of N1s and N2s. In order to control for such effects, we chose only four different N1s and combined each with an N2 triggering internal plural and one not triggering it. Given the four N1s, combining internal-plural N2s and non-internal-plural N2s with PL and NPL created sixteen targets for the initial plural sub-experiment alone. So that participants were not exposed to all sixteen of these, we randomised the items and participants saw either the version with PL or with NPL of any one N1+N2 combination. For the external plural sub-experiment, we only used N2s which could not trigger internal plural meaning, and we therefore decided that increased variety of N1s was better and used eight different N1s.

Participants declared themselves to be native speakers of German with no reading disorders. They were recruited in first-semester linguistics classes at Freie Universität Berlin during the first four weeks of the summer 2017 term. They were all majoring in German Language and Literature but had not yet had a university-level introduction to

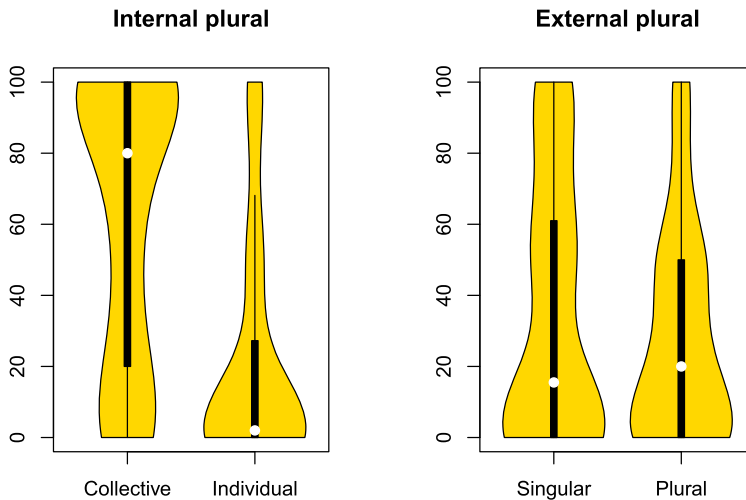


Fig. 5 Distribution of Split-100 responses in both sub-experiments by conditions

linguistics. We had 31 participants. 24 participants declared themselves to be female, seven to be male. Age varied between 19 and 31 with a median of 21.

5.2 Results

The results are clearly in line with the findings from the corpus study reported in Sect. 4. Figure 5 shows the distribution of the split-100 responses in the form of violin plots. Notice that all ratings were re-mapped such that 0 represents a clear preference for NPL and 100 a clear preference for PL, although in the actual experiment, the assignment of 0 and 100 to the conditions was randomised.

The external plural sub-experiment (right panel of Fig. 5) clearly had a negative result. For both singulars and plurals, subjects strongly prefer a NPL (for singular compounds, the median and mean rating are 15.5 and 35.1, and for plural compounds, they are 20.0 and 28.2).

The internal plural sub-experiment (left panel of Fig. 5) had a clearly positive outcome. The median and mean with NPL are 2.0 and 20.8, but with PL, they are 80.0 and 61.7). Even a simple exploratory data analysis thus shows that a PL strongly co-occurs with forced plural semantics on N1.

Analysing split-100 experiments with inferential tools such as generalised linear mixed models (GLMMs) is not as straightforward as Ford and Bresnan (2013) seem to suggest. First, the dependent variable is something like a proportion or a percentage at each data point and cannot be treated as a count or a numeric variable for modelling purposes, because assumptions underlying the modelling algorithms (such as homogeneity of variance) would be violated. For proportions, beta regression can be used. However, subjects tend to assign ratings of 0 and 100 very often (see Fig. 6), which leads to so-called *zero inflation* and *one inflation* (see Zuur et al. 2009 for a detailed account of practical modelling with zero inflation targeted at practitioners).

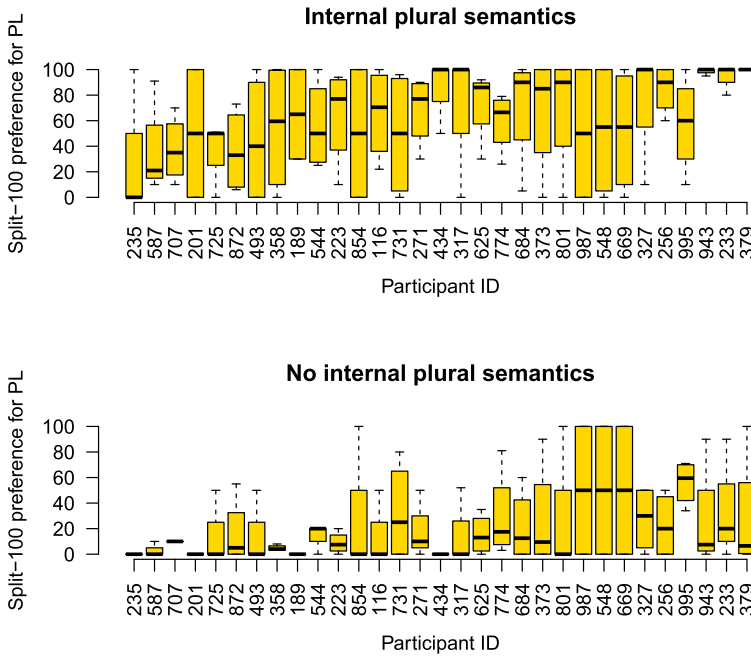


Fig. 6 Boxplots of the distribution of individual (per-subject) split-100 responses in the internal plural sub-experiment by conditions; subjects were ordered from left to right by their mean rating across both conditions

Since in the case at hand, we should also account for subject-level variation by including a random effect, the appropriate model is a *zero- and one-inflated mixed beta model*. The fact that control for subject-level preferences is important is illustrated by Fig. 6, where individual preferences in the internal plural sub-experiment are shown per condition.

A package for R which implements zero- and one-inflated mixed beta models is *gamlss* (Rigby and Stasinopoulos 2005). It is actually suitable for fitting general additive mixed models (GAMMs), but GLMMs can be fitted as a special case of a GAMM. In this case, no smoothing function is fitted for the fixed parameters, and a special smoother (*random()* in *gamlss*) is used for grouping factors to be used as random effects. We estimated the parameters of a GAMM specified as $\text{Rating} \sim \text{Condition} + \text{random}(\text{Subject})$ based on the data from the internal plural sub-experiment with the *BEINF* family for inflated beta models ($n = 248$).¹³ Ratings had to be mapped from $[0, 100]$ to $[0, 1]$. The only parameter of interest in the current setting is the coefficient for the *Condition* variable, which is estimated at -0.893 with an estimated standard error of 0.195 . It reaches $\text{sig} = 0.05$ ($t = -4.585$, $p \approx 0$). The model has an AIC of 517.008 . In comparison, a model without the predictor of interest ($\text{Rating} \sim \text{random}(\text{Subject})$) has an AIC of 531.801 , which is worse

¹³Technically, the given formula is the formula for the μ parameter.

by 14.793. In other words, the model corroborates the descriptive analysis in Fig. 5 using advanced inferential tools.

In the present experiment, subjects showed very clear reactions to different potential sources of plural semantics. The external plural condition did not trigger PLs more than NPLs, but there is solid evidence that speakers favour a PL in compounds where an internal plural relation holds between N1 and N2. In Sect. 6 we will discuss the theoretical implications of this result together with that of the corpus study reported in Sect. 4.

6 Conclusion

Both in the corpus study (Sect. 4) and the split-100 experiment (Sect. 5), we found evidence that writers prefer to use a PL when N1 necessarily has a plural interpretation due to compound-internal semantics (internal plural effect). We found no evidence for a similar influence of a plural suffix on the whole compound (external plural effect). The latter effect could either have been semantically motivated in some cases or be a simple compound-internal number agreement tendency, neither of which appear to be the case. In light of the suspicions raised in the literature that there might be plural effects within German compounds, as well as the previous research on Dutch linking elements (see Sect. 2.2.1), our results do not come as a surprise. Regardless of the diachronic development of linking elements, writers use PLs as cues to the interpretation of N1+N2 compounds (see also Banga et al. 2013b, 212). The form of an N1 with a PL is one which writers associate strongly with semantic plurals, and it appears that they do so also when that form occurs in a compound. A detailed look at our results reveals more about the actual mechanisms at work.

First, the effect strengths in the corpus study were weak to intermediate, and while the observed effect was clearer in the split-100 experiment, we are nowhere near a categorical split. There is also substantial per-speaker variation and uncertainty. (Readers can revisit Fig. 5 and Fig. 6 to convince themselves that this is the case.) So, we have to answer the question of why the overall effect is not stronger. As pointed out in Sect. 2.2.1, Banga et al. (2013a, 45) suggested that there may be a general tendency to avoid linking elements, based on the finding by Libben et al. (2002) that compounds with linking elements come with higher processing costs. This could account for the high percentage of zero linking elements (see Sect. 3.2, especially Table 2). Furthermore, regardless of whether one favours a rule-based or a similarity/exemplar-based view (see Sect. 2.1.2), in many cases the use of a PL is highly unlikely for unrelated reasons such class membership or phonotactics. A clear case are words ending in full vowels, which have an *-s* plural but resist *-s* linking elements strongly. For example, *Auto-s+kollektion* ‘car collection’ is very unexpected—according to some sources, even impossible (Wegener 2003, 2005; Fuhrhop 1996)—and *Auto+kollektion* would be preferred by a huge margin. Such factors stand in the way of establishing a stronger link between PLs and plurality.

Second, we must ask why the corpus-based results were weaker than the split-100 results. We propose that this is due to the fact that we made a considerable effort to ensure that the items in the experiment consisted of compounds which were most likely

novel to the subjects (see Sect. 5.1). In creating the samples for corpus study, however, we did not differentiate between compounds strongly established in language use and novel compounds. Therefore, the corpus sample contains lexicalised compounds with conventionalised idiosyncratic linking elements. Of course, we would expect that even lexicalised compounds follow the tendency to associate PLs with plural meaning at least to some extent. Thus, simply filtering compounds which have a high token frequency from concordances could obscure part of the picture and may not be in our best interests when trying to study this phenomenon. More theoretical, empirical, and even methodological work on this is clearly required.

Third, we must ask why PLs differ with respect to their tendency to be used to mark plurality in the corpus study. (The number of possible stimuli in the experiment was too low due to constraints imposed by the experimental procedure to allow a more differentiated look at variation between PLs.) The order of preference established in Sect. 4 (especially Fig. 4) was $=e \gg =er \gg -er \gg = \gg -e \gg -en \gg -n$. The strength of the internal plural effect is thus by and large negatively correlated with the type frequency of nouns which take the respective plural (see Sect. 3.2, especially Table 2, and Sect. 4.1, especially Fig. 2). Additionally, the inflectional suffixes *-en* and *-n* occur in many positions in German nominal inflection and therefore provide the lowest cue validity for plurality. For example, there is a dedicated dative marker *-(e)n* attaching to all plurals except *-(e)s*, where it is excluded for phonotactic reasons. Also, weak nouns mark all non-nominative singular forms with *-(e)n*. Finally, the so-called *weak* and *mixed* adjectives end in *-en* in all oblique (dative and genitive) singular forms and the masculine accusative singular. On the other hand, *-er* is much more exclusively a plural marker (with some exceptions in the so-called *strong* adjectival paradigm), and umlaut is clearly reserved to mark plural in German nominal inflection.¹⁴ In short, stem umlaut is a highly salient cue, whereas *-e* (schwa) and *-(e)n* (usually realised as a syllabic nasal) are the least salient of plural markers. Taken together, this means that plural interpretation of PLs is stronger with what Köpcke (1993) calls a higher *Signalstärke* ‘signal strength’ of the PL as a plural marker. His criteria for high signal strength are high salience, high validity, low type frequency, and a high degree iconicity.¹⁵ We conclude that writers associate plural meaning more strongly with PLs if the PL itself is more strongly associated with plurality, i.e., has greater signal strength. Furthermore, we consider it likely that the correlation between type frequency in our sense and the increased tendency for plural interpretation of PLs is merely accidental. The more salient and cue-valid plural patterns happen to be the less type-frequent ones for historical reasons.

Fourth, an explanation of why only the internal plural effect was observed is necessary. In Sect. 1, we argued that restrictive frameworks tend to elevate universal tendencies to hard universal constraints. Among the proposed morphological constraints

¹⁴Some comparative and superlative adjectives take an umlaut in addition to the corresponding suffixes, but the formation of comparatives is clearly something very different from case and number inflection. Also, case and number inflection attaches additionally to the right of the comparative suffix.

¹⁵We do not discuss the more complicated notion of iconicity here for reasons of space. By type frequency, Köpcke means the number of different forms in a paradigm, and what we have described as cue validity above encompasses Köpcke’s validity and type frequency. For us, type frequency is rather the number of different nouns with which a plural marker occurs.

were those requiring that there be no inflection inside products of word formation. We would like to point out that the tendencies that we have uncovered concern the internally licensed inflectional category of number only (see Sect. 2.2.1). We found no evidence that case marking occurs on N1, nor are we aware of any such evidence. Case could conceivably only be used to specify the grammatical relation between a compound's constituents, and this is something not usually found in compounds, but rather in complex noun phrases. Number, on the other hand, has nothing to do with the grammatical relation between the constituents. Writers use the optional plural marking when the individual and joint conceptual representation of the constituents allows this, but it has nothing to do with syntagmatic grammatical relations. However, the external plural effect would require that a formed compound be somehow transparent for grammatical categories attaching to its whole. This is atypical of compounds.

Fifth, we would like to propose an explanation of why our findings seemingly contradict those of Koester et al. (2004). They show in an experiment using event-related potentials (ERP) that mismatches between the semantic (non-)plurality of N1 and PLs/NPLs do not lead to the expected N400 effect, concluding that PLs and NPLs are not used by hearers to decode the conceptual structure of N1+N2 compounds. In contrast to the ERP experiment, we only considered the production side of the effect by looking at usage data from a corpus and preferences in a production-oriented decision task. Since plurality is only marked optionally within compounds, as we have argued extensively above, hearers cannot and need not rely on PLs as plural markers. However, the fact that hearers do not rely on plural marking does not necessarily prevent writers from using plural forms where a plural meaning is intended. This, then, raises the question of whether the plural is really *marked* or just redundantly indicated by a PL. Only further research can shed light on such questions.¹⁶

Sixth and finally, Banga et al. (2013a) found that German L2 learners of Dutch do not react as strongly to the Dutch PL *-en* as Dutch L1 speakers. This could be due to the fact that, as we have shown and explained, Germans attribute the lowest plural interpretability to *-en* in German, rather than due to an across-the-board weakness of the relationship between plurality and PLs in German, as the authors speculated (Banga et al. 2013a, 45). If there really is an interference effect from the German L1, then the Dutch marker being accidentally identical to the German marker with the lowest signal strength would naturally lead to low affinity for a plural interpretation in compounds. For Dutch speakers, however, given the complete absence of nominal case inflection and much reduced system of plural markers, differences in signal strength are irrelevant.

In conclusion, our study has helped to show that German PLs can indeed have a plural interpretation. More importantly, we have shown that there are differences in when this interpretation is available: primarily, when the head of the compound is a collective noun. This forces a plural interpretation upon the N1 which represents multiple members of this collective, and this plural interpretation is reflected in an inclination toward the interpretation of a pluralic linking element as a plural marker. We

¹⁶Some relatively simple experiments could provide clarification about the reception of PLs. These could involve subjects associating objects or illustrations with truly ambiguous compounds such as *Apfel+teller* 'apple plate' and *Äpfel+=teller*. For more implicit testing, the task might be set up in the visual world paradigm.

have also provided cognitively oriented explanations for why the plural interpretation is available in some situations and not others. We see many possible routes for future research on the subject. For example, more refined corpus studies taking into account the degree to which a compound is novel or established should be made. Also, the differences between the production and the reception side of plurality in compounds need further research, especially considering that for each side, only one study has been conducted (namely Koester et al. 2004 and this one). While there appears to be a solid connection between PLs and plurality, this connection's exact nature still remains to be characterised fully.

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Compliance with ethical standards The split-100 rating experiment reported in this paper was completely anonymised. Participants signed standard consent forms and were given the option of asking questions about the nature of the experiment before and after they took part in it. They were granted the right to revoke their signed declaration of consent (through anonymised personal codes), which none of them did. Participants received no payment, but they were awarded credit in partial fulfillment of the requirements for a first-semester class in German linguistics at Freie Universität Berlin. The participants could specify their gender on a voluntary basis and they were given no pre-formulated options.

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