

# Between syntax and morphology: German noun-verb units as reluctant compounds

Roland Schäfer  
*Deutsche Sprache und Linguistik,  
Humboldt-Universität zu Berlin*  
Dorotheenstraße 24, 10117 Berlin  
roland.schaefer@hu-berlin.de

Ulrike Sayatz  
*Deutsche und niederl. Philologie,  
Freie Universität Berlin*  
Habelschwerdter Allee 45, 14195 Berlin  
ulrike.sayatz@fu-berlin.de

**Abstract ...**

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## 1 Introduction

### 1.1 Grammar, graphemics, and usage

Usage-based Grammar (UBG; e. g., Bybee & Beckner 2009; Kapatsinski 2014; Tomasello 2003) is based on two core assumptions: (i) grammar is acquired using only general cognitive devices, (ii) only the input and general cognitive constraints determine the grammar. Since the input is always rife with variation and often non-discrete, a third assumption is crucial to some researchers: (iii) grammars are learned as probability distributions over possible forms, meanings, and form-meaning pairs. We embrace all three assumptions and apply them to a graphemic alternation phenomenon wherein certain noun-verb combinations in present-day German can be spelled as one word or two words. UBG is rarely extended to graphemics in such a way, but we view graphemics as a component of the language faculty on a par with components such as phonetics and phonology, and we consequently believe that graphemics should be viewed under the usage-based umbrella.<sup>1</sup> While the phono-component comprises regular-

<sup>1</sup> The huge body of work in different strains of linguistics based on popular corpora of written language has an intrinsic graphemic component, simply because written data are used.

ities of how grammar is encoded in speech sounds, graphemics comprises similar regularities of how grammar is encoded in written symbols. Whether and how strongly the phono-component and the graphemics component are intertwined is determined by the type of script and the specific language, where ideograph-based writing systems like early cuneiform Sumerian (virtually complete separation) and phonographic writing systems like German (substantial overlap) represent extremes on a continuous scale. For writing systems like German, the mappings to be learned include sounds to letters, parts of speech to spellings (e. g., capitalisation), syntactic categories to spaces and punctuation marks, etc.<sup>2</sup>

In UBG, corpus data (i. e., production data) are often used as evidence, sometimes cross-validated in behavioural experiments (see, for example, Arppe & Järvikivi 2007; Bresnan et al. 2007; Dąbrowska 2014; Divjak 2016; Divjak, Dąbrowska & Arppe 2016; Ford & Bresnan 2013; Schäfer 2018). This is justified because the probabilistic usage-based nature of the acquisition process as described at the outset should be reflected in the grammars of competent adult speakers/writers and not just in the acquisition process itself. Consequently, it should also be reflected in production data obtained from competent adults, and we should be able to uncover the probabilistic mappings of lexical-grammatical categories to written forms from such data. We consequently use corpus data as well as data elicited in controlled experiments, both being forms of production data. However, there is a difference between using production data as evidence and assuming that they *directly* mirror cognitive reality. While it is generally assumed that corpora represent a valid source of data in cognitively oriented linguistics (e. g., Newman 2011), it is also known that there is no straightforward correspondence between corpus data and cognitive reality (e. g., Gries 2003; Dąbrowska 2016). What we hope to recover from corpus data are major abstractions learned by a majority of speakers, uncovering general cognitive principles that ideally go far beyond individual acquisition careers and idiosyncrasies of single languages.

A convenient framework to formulate such abstractions is Prototype Theory (Rosch 1973; 1978). As a cognitive theory of classification, it is compatible with probabilistic views inasmuch as it allows for fuzzy category membership (e. g., Sutcliffe 1993; Murphy 2002: 11–16). Grammatical

While it might not be problematic for most studies that this is rarely acknowledged, we consider it important to focus on this component as well.

<sup>2</sup> Notice that a probabilistic view does not necessarily imply that there are no discrete or virtually discrete mappings like the one-to-one mapping of consonantal segments to letters in German. Cases of discreteness can always be seen as extremes in a probabilistic system.

units can thus be modelled as belonging to multiple categories to different degrees or—in our case to be introduced immediately below—as alternating between a morphological and a syntactic realisation.<sup>3</sup> Prototype Theory is also intrinsically compatible with UBG as it assumes just a very general mechanism of classification whereby newly encountered objects are classified by similarity to a prototypical exemplar. In most versions of Prototype Theory, these prototypes are identified by (weighted) features or *cues*, and unseen exemplars are categorised depending on how many of those features they share with the prototype. We use Prototype Theory as a suitable framework in our analysis. Grammatical prototypes are mapped onto graphemic realisations (e. g., spellings), and the stronger a unit matches the prototype, the more likely it is to be realised as mapped.

One caveat that is specific to graphemics needs to be mentioned before we proceed to the description of the concrete phenomena. The acquisition of the writing system involves explicit instruction and is thus more strongly superimposed by prescriptive norms. However, we expect writers to learn grammar-graphemics mappings first and foremost from their realisations in the input, especially whenever the norm is unspecific or unclear, a situation which provides ideal test cases for our view of graphemics. Variation and alternations in the written input shape the acquired probability distribution, and conditioning factors are acquired to the degree that they can be retrieved from the type and the frequency of the input.<sup>4</sup>

## 1.2 Introducing N+V units in German

The alternation we are going to explore affects units containing a verb and a noun, and these units alternate between a syntactic manifestation (where the noun combines with the verb via a syntactic relation) and a morphological one (where the noun is incorporated into the verb). We will argue that alternations in spelling provide evidence for the grammatical status of the instances of the construction. Simple examples not showing the alternation are given in (1).

- (1) a. Remy fährt Rad.  
       Remy rides<sub>V</sub> bike<sub>N</sub>  
       Remy is riding/rides a bike.

<sup>3</sup> For applications of Prototype Theory in linguistics see, among many others, Divjak & Arppe (2013); Dobrić (2015); Gilquin (2006); Gries (2003); !Schäfer (2019). See Taylor (2003; 2008) for introductory overviews.

<sup>4</sup> We have previously used a similar approach in, for example, !Schäfer & Sayatz (2014; 2016).

- b. Remy läuft Eis.  
 Remy runs<sub>V</sub> ice<sub>N</sub>  
 Remy is ice-sakting/ice-skates.

In this construction, there is a noun N occurring in its bare form, which either corresponds to an argument of the verb V (normally in the accusative case) as in (1a) or to an adjunct of the verb V as in (1b), which would normally take the form of a prepositional phrase.<sup>5</sup> We use the terms ‘argument relation’ and ‘oblique relation’ to refer to the semantic relation between the noun and the verb in the former and the latter case, respectively, following Gaeta & Zeldes (2017: 20). Oblique nouns occur without their usual preposition, and since the accusative case is only morphologically encoded on determiners (if at all) in German, the relation between the noun and the verb is never formally encoded in either case. Furthermore, the noun always acquires an unspecific generic reading: In examples such as (1a), *Rad fahren* (‘to ride bike’) refers to the concept of riding any bike, and the unspecific reading of *Rad* is obligatory, which is not the case for the English translations with the indefinite article.

German clausal syntax creates the conditions for the actual spelling alternation to occur, see (2).<sup>6</sup>

- (2) a. Remy **fährt** gerade **Rad**.  
 Remy rides<sub>PRES</sub> right now bike  
 Remy is riding a bike right now.
- b. Yael weiß, dass Remy **Rad fährt**.  
 Yael knows that Remy bike rides<sub>PRES</sub>  
 Yael knows that Remy is riding a bike.
- c. Remy ist gestern **Rad gefahren**.  
 Remy is yesterday bike ridden<sub>PART</sub>  
 Remy rode a bike yesterday.
- d. Remy will **Rad fahren**.  
 Remy wants bike ride<sub>INF</sub>  
 Remy wants to ride a bike.

<sup>5</sup> Whereas singular indefinite mass nouns typically occur without an article in German (Vogel 2000: 471), this is the only frequent construction in German wherein bare count nouns occur. However, there is a class of lexicalised light verb constructions where a bare noun occurs with a light verb, such as *Anklage erheben* ‘indict’, literally ‘to raise indictment’. Like idiomatic expressions such as *Leine ziehen* ‘get lost’, literally ‘to pull leash’, they do not instantiate a productive pattern (Hentschel & Weydt 2003: 76, Stumpf 2015: 198). Consequently, we do not discuss them further.

<sup>6</sup> Further spelling variants for (2c) through (2h) will be discussed immediately below.

- e. Remy hat keine Lust, **Rad zu fahren**.  
Remy has no motivation bike to ride<sub>INF</sub>  
Remy doesn't feel like riding a bike.
- f. Remy ist am **Rad fahren**.  
Remy is at the bike ride<sub>INF/NOUN</sub>  
Remy is riding a bike.
- g. Remy singt beim **Rad fahren**.  
Remy sings upon the bike ride<sub>INF/NOUN</sub>  
Remy is singing while riding a bike.
- h. \* Remy lobt das **Rad fahren**.  
Remy praises the bike riding<sub>NOUN</sub>  
Remy praises the riding of bikes.

Such N + V units occur flexibly in all types of syntactic contexts: with finite verbs in verb-second order (2a), with finite verbs in verb-last order (2b), in the analytical perfect where the lexical verb takes the form of a participle (2c), in bare infinitives (2d), in infinitives with the particle *zu* (2e), in a progressive-like construction with the preposition *an* fused with the dative singular article *dem* to *am* where the infinitive is potentially nominalised (2f), and in regular prepositional phrases (2g). In (2h), the spelling of the N + V unit as two words is impossible, hence the asterisk. In this case, we can assume that the noun and a fully nominalised infinitive form a regular nominal compound.<sup>7</sup> The spelling as two words for (2f) and (2g) is not accepted by all native speakers.

In the examples (2c) through (2h), the noun and the verb occur in sequence without intervening material. In these cases, the noun and the verb alternate between the spelling as multiple words seen in (2) and spellings as one word shown in (3).

- (3) c. Remy ist gestern **radgefahren**.
- d. Remy will **radfahren**.
- e. Remy hat keine Lust, **radzufahren**.
- f. Remy ist am **Radfahren/radfahren**.
- g. Remy singt beim **Radfahren/radfahren**.
- h. Remy lobt das **Radfahren**.

<sup>7</sup> Infinitives in German can be routinely nominalised as an action noun (Gaeta 2010: 224, Dammel & Kempf 2018: 67, Werner, Mattes & Korecky-Kröll 2020: 172–174).

In (3f) and (3g), additional variation is introduced in the form of upper-case and lower-case initials.<sup>8</sup> The compound with the nominalised infinitive in (3h) is fine if spelled as one word.

We call cases where a multi-stem unit is spelled as two words such as in (2) ‘disjunct spellings’ and cases where a unit is spelled as one word as in (3) ‘compound spelling’. We see that N + V units potentially undergo graphemic *univerbation* in the form of compound spelling. Lehmann (2021: 2) calls univerbation “the union of two syntagmatically adjacent word forms in one”. We follow this terminology and assume univerbation to be the directly observable phenomenon, i. e., compound spelling of adjacent words that could potentially also be used in disjunct spelling or were historically used in disjunct spelling. Historically, univerbation is a gradual process, and it can thus be a strongly probabilistic phenomenon due to the slowly changing grammatical and lexical system. However, univerbation per se is not necessarily the result of a regular grammatical pattern or process.<sup>9</sup> Thus, a major aim of this paper is to show whether and how the univerbation of N + V units in German is based on an established morphological prototype construction wherein a noun is incorporated into a verb, forming a new verb expressing a new event concept.

We will argue that such a morphological construction exists, but that the alternative syntactic construction remains available to speakers because N + V units have properties of both morphological as well as syntactic prototypes. In Section 2, we lay the theoretical and descriptive foundations. We then present a large-scale corpus study and an elicitation experiment in Sections 3 and 4, exploring our particular hypotheses about N + V units. We conclude with a summary, further interpretation and discussion in Section 5.

## 2 Theoretical and descriptive background

In this section, we lay the theoretical and descriptive foundations of our analysis of the alternation described in Section 1. First, we clarify the status of spaces (i. e., *spatia*) as syntactic boundaries in German in Section 2.1.

<sup>8</sup> In German, all nouns are capitalised anywhere in a sentence (Pauly & Nottbusch 2020: 1).

<sup>9</sup> For Gallmann (1999: 294) univerbation is a diachronic process wherein a complex syntactic unit is reanalysed as a simplex syntactic unit. Jacobs (2005: 107) regards graphemic univerbation as not rooted in a morphological process as they are not paradigmatic (no *Reihenbildung*). Lehmann (2021: 4) is closest to our position as he regards “univerbation as a gradient process which displays phases of weaker and stronger univerbation”. According to him, it marked by the loss of morphological boundaries and phonological fusion.

Then, we discuss previous analyses of N + V units and their spelling, followed by the formulation of our predictions for the empirical studies in Section 2.2.

## 2.1 Spaces, words, and universion

As explained in Section 1, we use graphemic evidence from corpora and controlled experiments, and we argue that it indirectly allows us to draw conclusions about writers' cognitive grammars. More specifically, we assume that compound spellings of N + V units indicate that writers conceive of those units as single syntactic words, whereas disjunct spelling indicates that they conceive of the unit as two syntactic words. Therefore, we briefly introduce the status of the space in German writing and how it pertains to N + V units.

German writing uses an alphabetic script with a strong correlation between underlying phonological forms (the phonemic level) and characters (graphemes). A common fundamental principle of such scripts is the separation of syntactic words by spaces (Jacobs 2005: 22). Also, stems and their affixes are never separated from one another, which reinforces the status of the space as a demarcation of syntactic words.<sup>10</sup> These factors facilitate the reader's ability to decode the sequence of syntactic words, and they constitute a crucial principle in the encoding and conventionalisation of meanings associated with word forms (Jacobs 2005: 22).

Unlike in English, compound spelling of syntactic words comprising more than one stem was also established in the history of German writing, especially for the case of the highly productive noun + noun (N + N) compound pattern (Fuhrhop 2007: 182, Jacobs 2005: 34, Section 2.2 below), for which compound spelling is the dominant graphemic realisation. However, there is a heterogeneous group of multi-word constructions for which only a tendency towards compound spelling can be observed (Szczepaniak 2009: 95, Wurzel 1998: 335). As opposed to N + N compounds, these constructions typically consist of words with different parts of speech, such as *mithilfe (von)* ('with the help (of)') from *mit der Hilfe (von)* or *zu Hause*

<sup>10</sup> There is a class of verbal particles which does not follow this principle. Verbs like *aufessen* ('eat up') formed from a verb stem (*essen*) and a prefixed particle (*auf*) are spelled as one word when they are adjacent in verb-last order, but they are separated in verb-second order where the verb is moved to sentence-second position and the particle remains in sentence-last position through obligatory long-distance movement (see Hoberg 1981 for an account of German clausal and sentential syntax).



(‘at home’) from *zu Hause*.<sup>11</sup> For such cases, [Lehmann \(2021: 2\)](#) posits a “downgrading of a syntactic to a morphological boundary” between the two words. When writers use compound spelling in these cases, they choose to encode the construction as a single word with a morphological boundary instead of a sequence of words with a syntactic boundary. If many speakers consistently make this choice over a significant period of time, the unit might become lexicalised as a single word ([Lehmann 2021: 7](#)). Until such a diachronic process is complete and one of the spellings has become clearly dominant, lexicalisation does not provide a very strong input to writers, and the item alternates between a syntactic and a morphological realisation. For many of these constructions, this is the case both in non-standard as well as standard written German, albeit to different degrees.<sup>12</sup>

N + V units with different affinities towards compound spelling like *Rad fahren* (‘bike riding’, often also spelled *radfahren*) and *eislaufen* (‘ice skating’, infrequently also spelled *Eis laufen*) represent different levels of diachronic re-conventionalisation as single words.<sup>13</sup> This indeterminacy means that speakers have both the syntagmatic realisation (disjunct spelling) and the morphological realisation (compound spelling) in their graphemic input, which subsequently leaves them with quite a free choice to be made based on how a concrete item is classified according to their individual grammar. It is the task of usage-based probabilistic graphemics to uncover factors influencing such decisions and decode the principles at work in speakers’ internal grammar by analysing their writing habits (see [!Schäfer & Sayatz 2016](#)).

## 2.2 The status of noun-verb units in German

In Section 1, we showed that N + V units alternate between compound spelling and disjunct spelling when they occur in sequence. In this section, we ex-

<sup>11</sup> Normative approaches as well as individuals display a lot of variation with respect to at least some of those constructions (cf. below).

<sup>12</sup> We are not aware of any published research systematically comparing the alternation tendencies in standard and non-standard written German.

<sup>13</sup> The orthographic norm is notoriously unstable with respect to N + V units, which contributes to their unclear status. Before the significant reform of the orthographic norm in 1996, both *radfahren* and *eislaufen* were supposed to be spelled as one word. After the reform, both units were supposed to be written as two words (*Eis laufen* and *Rad fahren*). After a revision of the reform in 2006, *eislaufen* was again supposed to be spelled as one word, whereas *Auto fahren* was supposed to be spelled as two words exclusively ([Primus 2010: 32](#), [Eisenberg 2020: 356](#)). From experience, we know that the norm is often not adhered to, and the data presented in Sections 3 and 4 strongly corroborate this experience.



plain why the existence of this alternation is not surprising considering the morphosyntactic system of German. Furthermore, we argue that in each concrete case where an N + V unit is written, the strength of the tendency towards either compound or disjunct spelling can be derived from the overall syntactic and morphological patterns available in present-day German. These patterns are shown to have prototypical properties which are matched by individual N + V units and their syntactic contexts more or less well, which leads to either compound or disjunct spelling being the preferred realisation. The hypotheses put forward here are then evaluated empirically in Sections 3 and 4.

To this end, we need to shed some light on the productive N + N compound construction in Section 2.2.1 before turning to N + V units as reluctant compounds in Section 2.2.2. We sum up our arguments and derive our hypotheses for the empirical studies in Section 2.2.3.

### 2.2.1 N+N compounds

For an N + V unit to undergo graphemic univerbation (i. e., a downgrading of a syntactic to a morphological construction in the sense of [Lehmann 2021](#): 2) systematically, it must resemble one or more established morphological constructions closely enough to be classified as an instance of such constructions itself.<sup>14</sup> We posit that this follows from the assumed underlying learning mechanisms under a usage-based perspective. The prototypical and arguably the only fully productive morphological construction combining more than one stem in German is noun + noun (N + N) compounding, to which we turn now in some detail.<sup>15</sup> German N + N compounds instantiate a proper morphological construction. Syntactically, nothing can intervene in between the two stems of the compound, and they cannot be rearranged. With minor exceptions (often exaggerated in normative discussions), they are also inseparable graphemically, i. e., they are always written as one word ([Scherer 2012](#): 57–60). Furthermore, they are always head-final, mostly determinative, and they allow recursive formation wherein an N + N compound enters into another N + N compound, resulting in [[N + N] + N] or [N + [N + N]] structures ([Fleischer & Barz 2012](#): 13). Some examples are

<sup>14</sup> Random isolated univerbations like *zu Hause* ‘at home’ from *zu Hause* are not systematic in this sense. They are merely the result of idiosyncratic diachronic developments.

<sup>15</sup> Adjectives also enter compounds as the head, such as in *feuerrot* ‘red like fire’, literally ‘fire red’. However, this pattern is much less productive than N + N compounding, and we do not discuss it here. See [Simunic \(2018: 136\)](#) on the productivity of N + A compounds.

given in (4) and (5) for *Haustür* and *Haustürschlüssel*, the latter being recursively formed from the former.<sup>16</sup>

- (4) Haus.tür  
house.door  
front door
- (5) Haus.tür.schlüssel  
[[house.door].key]  
key to the front door

The semantic relation between the first noun ( $N_1$ ) and the second noun ( $N_2$ ) is highly unspecific, rendering many compounds semantically ambiguous unless they are strongly lexicalised (Klos 2011: 252).<sup>17</sup> The historic development of the stable N + N compound construction was furthered during the Early High German period (approximately from the 14th to the 17th century AD) by a syntactic change.<sup>18</sup> The dominant pattern of noun–noun attribution had been a prenominal genitive as in the now obsolete (6), which swiftly changed to a postnominal genitive as in (7).

- (6) † des Hauses Tür  
the<sub>Gen</sub> house<sub>Gen</sub> door  
the door of the house
- (7) die Tür des Hauses  
the door the<sub>Gen</sub> house<sub>Gen</sub>  
the door of the house

To the extent that prenominal attribution in syntax became more and more obsolete, the prenominal position was used to establish the highly productive morphological construction of N + N compounds as in (4) (see Nübling et al. 2017: 132, Schlücker 2012), which showed a tendency to be written in compound spelling very early on (Dücker & Szczepaniak 2017:

<sup>16</sup> If necessary, we present compound spelling with a minimal analysis of the morphological structure. Affixes are separated from stems by hyphens, and lexical stems are separated from each other by a period. Within compounds containing more than two stems, structure is using square brackets as in examples (8) and (9) below.

<sup>17</sup> Obviously, once they are strongly lexicalised, they cannot help to establish a more canonical type of semantic relation between  $N_1$  and  $N_2$ , either, simply because lexicalised compounds are often intransparent to the language user (Klos 2011: 59), such as *Kammerjäger* ('pest controller', literally 'chamber hunter').

<sup>18</sup> Nübling et al. (2017: 130) find that the prenominal genitive begins to give way to the postnominal genitive in the 13th century. Around 1500, already 53% of the genitives are postnominal, rising to 64% at around 1700.

34–36). The N + N compound construction is semantically at least as un-specific as the syntactic genitive construction to which it is diachronically related (Eisenberg 2020: 239). Its recursive application is virtually unrestricted (Wurzel 1994: 504).  $N_1$  and  $N_2$  are just concatenated as bare stems in most cases, but there are also so-called linking elements, which are sometimes positioned in between the stems.<sup>19</sup> Diachronically, linking elements stem from diverse sources, but the overall pattern of inserting them is related to the former morphological marking in prenominal genitives (Nübling et al. 2017: 55–57).

N + N compounds as described in this section are clearly the prototype for morphological constructions combining more than one stem in German. In the next section, we show how N + V units deviate from this prototype, and how this keeps them from univerbating fully and stably.

### 2.2.2 N+V units as reluctant compounds

In this section, we argue that N + V units are *reluctant compounds*. Some factors pull away from compounding and univerbation, other factors pull them towards it. While in principle the morphological N + V construction (as a kind of compound written as one word) has existed for centuries, we show why and how it remains in competition with a syntactic construction because it does not fit the morphological compounding prototype very well. At the same time, we argue why morphological compounding and consequently the spelling as one word (univerbation) become the preferred realisation under the right circumstances.

Most likely, full compounding of N + V units requires conversion of the verbal head to a noun, making the result an N + N compound via conversion. As opposed to compounding with proper nominal heads (as discussed in the previous section), compounding with verbal heads is not a productive pattern in German.<sup>20</sup> A major difference to N + N compounds is the fact that N + V units are usually not inseparable as was already shown in Section 1. There can be intervening material in between the noun and the verb in some contexts, namely the infinitival particle *zu*. This particle is, however, virtually part of the verbal word form and does by no means prevent univerbation (see example 3e). Furthermore, the noun and the verb

<sup>19</sup> A recent large-scale study (Schäfer & Pankratz 2018: 339) showed that 60% of all N + N compound types have no linking element, whereas 40% have one of several possible linking elements.

<sup>20</sup> Günther (1997) counts roughly 400 lexicalised N + V compounds in Muthmann (1988) (see also Eisenberg 2020: 245).

can be reordered in verb-second order, where N + V units resemble particle verbs (Fortmann 2015: 603), see (2a). This fact alone means that N + V units do not fit the compounding prototype anywhere near perfectly. This likely introduces great resistance in speakers to classify them as compounds and use compound spelling.

Another major difference between N + N compounds and N + V units is that the morphological N + V construction is not recursive. Nominalised N + V units marginally occur as  $N_1$  in  $N_1 + N_2$  compounds (contrary to claims by Fuhrhop 2007: 54) as in (8).<sup>21</sup> However, an N + V unit cannot function as the verbal head in another N + V unit (i. e., a  $[N + [N + V]]$  structure) as illustrated in (9). Native speakers will readily acknowledge that such constructions are outright absurd.

- (8) a. *Energie.spar.messe*  
       [[energy.save].fair]  
       trade fair for products useful in saving energy
- b. *Endlager.such.gesetz*  
       [[final storage.search].law]  
       law about the search for a permanent repository for nuclear waste
- c. *Feuer.lösch.boot*  
       [[fire.extinguish].boat]  
       fire-fighting boat
- (9) \* *Rad.fahr.mach-en*  
       [[bike.ride].make-INF]  
       make bike riding

We posit that the lack of core properties of prototypical (productive) German compounding constructions (separability, potential reordering, lack of recursive application) is a major factor in keeping the formation of N + V units from establishing a fully productive morphological compounding construction, thus keeping it from reliably requiring graphemic univerbation.

Another noticeable difference between the N + N and the N + V construction is the specificity of the internal relation. While the relation in N + N compounds is quite varied as well as unspecified and unspecific (see Section 2.2.1), there are only two possible relations within N + V units, and

<sup>21</sup> The examples in (8) are attested and taken from the DECOW16B web corpus (see Section 3.1). Their document frequencies are 218 for *Energiesparmesse*, 416 for *Endlagersuchgesetz*, and 414 for *Feuerlöschboot* in a corpus of 17.1 million documents. The document frequency is the number of documents the lemma occurs in, not counting multiple occurrences within each document.

these relations are determined by the verb's argument structure. It's either an argument relation or an oblique relation where all distributional restrictions apply that would apply in a syntactic realisation of the same verb. As a consequence, there is always a syntactic paraphrase for N + V units with an oblique relation where the noun occurs in a prepositional phrase which is an adjunct to the verb.<sup>22</sup> See (10) for an example.

- (10) a. Kim will die Corvette probefahren.  
           Kim wants the Corvette test.drive  
           Kim wants to test-drive the Corvette.  
       b. Kim will die Corvette zur Probe fahren.  
           Kim wants the Corvette to the test drive.  
           Kim wants to test-drive the Corvette.

The relation is decodable except in rare cases which underwent full lexicalisation such that the meanings of the lexemes or their distributions have changed significantly. However, both argument and oblique relations are prototypically realised in syntax as German is a language with a very weak (if any) tendency towards noun incorporation (see below in this section). Even if the verb is nominalised, direct objects are realised as genitives within the noun phrase, and adjuncts do not change their form when occurring within NPs containing nominalised verbs as heads.

The fact that the relation can be decoded for almost all N + V units means that the morphological construction marked by graphemic univerbation remains in competition with a syntactic construction with distinct syntactic words separated by spaces in writing. This competition between a morphological construction and a syntactic construction was pointed out with varying terminology by—among others—Fleischer & Barz (2012: 12), Schlücker (2012: 13), and Morcinek (2012: 88). Whereas the alternative syntactic construction for N + N compounds (the prenominal genitive) disappeared within a relatively short period of time, the ambiguity between syntax and morphology of N + V units remains intact. This is true although univerbation of N + V units with an argument relation dates back to Middle High German (*lobpreisen* 'praise', literally 'to praise compliment') and even Old High German (*hals-werfōn* 'turning around', literally 'to throw neck'), see Wurzel (1994: 517), Wurzel (1998: 334). For N + V units with an oblique relation, Morcinek (2012: 89) notices that dictionaries from between 1750

Correct gloss?

<sup>22</sup> Pragmatically, these paraphrases might often be subject to blocking because of the availability of the N + V construction. However, this does not make them syntactically or semantically unacceptable.

and 1993 AD list novel N + V units with an oblique relation with increasing frequency. For centuries or perhaps even more than a millennium, N + V units have been co-existing in syntax and morphology. We assume that the stable availability of an alternative syntactic realisation is yet another major factor in preventing N + V formation from becoming a more clearly morphological construction in language users' cognitive grammars, making N + V units *reluctant compounds*.

So far, we have focussed on the factors that speak against the compounding of N + V units. We still have to show why and under which conditions we assume true compounding and (including potential V-to-N conversion of the head and subsequent graphemic univerbation) to be preferred. As already mentioned, the morphological realisation of N + V units is a type of noun incorporation. N + V units are usually seen as the only cases of potential incorporation in Modern German (Eisenberg 2020: 245), which is why we argued above that argument and oblique relations are prototypically realised syntactically in the form of objects and adjuncts. According to Mithun (1984: 848), incorporation is “a particular type of a compounding in which a V and N combine to form a new V”.<sup>23</sup> As Mithun (1984: 848–849) points out, incorporation happens when the verb denotes a new and independent event concept in combination with the incorporated noun the semantics of which are determined by the previous syntactic relation between the noun and the verb. Typically, the noun loses its referential autonomy as well as its specificity, and it acquires a generic reading, which is indeed the case for N + V units. In sentences like (11), no specific bike is referenced, and *radfahren* refers to the whole concept of riding any bike. This is true for both compound and disjunct spelling.

- (11) Friedel kann radfahren/Rad fahren.  
 Friedel can bike.ride  
 Friedel knows how to ride a bike.

As a result of the semantic degradation of the noun, it loses its modifiability (also regardless of spelling), as illustrated in (12).

- (12) \* Friedel kann schnelles Rad fahren.  
 Friedel can quick bike ride  
 Friedel knows how to ride a quick bike.

<sup>23</sup> From Mithun's types of noun incorporation, German N + V units clearly represent type 1 *lexical compounding*. Since this is highly straightforward and homogeneous, we do not discuss the literature on the typological classification of incorporation further.

Such losses of referential autonomy and syntactic combinatorics are referred to as ‘noun stripping’ by Gallmann (1999: 287). The loss of specificity and referential autonomy as well as the acquisition of a generic reading are part of the semantics of the N + V construction (see also Gallmann 1999: 287, Bredel & Günther 2000: 108, Eisenberg 2020: 354). Functionally, the construction exists in order to express the new event concept which requires the generic/unspecific reading of the noun. Thus, the noun has the properties typical of nouns that are subject to incorporation of the lexical compounding type. In contrast with the factors that prevent univertation and make N + V units reluctant compounds, this is a factor that we assume to facilitate their univertation.

In the next section, we will summarise the factors that influence the tendency of N + V units to incorporate and undergo univertation. These factors will then be analysed in the empirical work to be reported in Sections 3 and 4.

### 2.2.3 Conclusions for the empirical studies

In the previous sections, we have laid out a theory of the factors leading to the univertation of N + V units. In this section, we derive some effects that we expect to see in written production data based on our overall usage-based framework (see Section 1) and our theoretical assessment of N + V units. These effects are then examined empirically in Sections 3 and 4.

In general, greater similarity to the N + N compound prototype and reduced competition from the full syntactic realisation are expected to favour univertation. An important cue for this prototype is a strongly nominal morphosyntactic context. Concretely, when the unit is embedded in an unambiguously verbal syntagma (e. g., when the V head is an infinitive dependent on a modal verb or a participle dependent on an auxiliary), we expect a low tendency towards univertation.<sup>24</sup> However, when the unit occurs in a strongly nominal syntagma (e. g., when the head is a fully nominalised head of an NP with a determiner), we expect a high tendency towards univertation due to an accessible interpretation as an N + N compound.

The second important cue is the internal semantic relation. As argued, N + V units with an oblique relation stand in weaker competition with a syntactic realisation compared with those that have an argument relation. N + V units with an oblique relation would need more explicit marking with

<sup>24</sup> Notice that when the V head is finite, the N and the V are always realised discontinuously, and univertation is not an option. The most prototypical verbal realisation is thus outside the scope of this study.



a preposition in the alternative unambiguously syntactic realisation. Also, for N + V units with an argument relation, there is the productive and functionally similar type of government compound of the form  $N_1 + N_2$  where  $N_2$  is obtained from a verb by morphological derivation (e. g., *Problemlösung* ‘problem solving’ where *Lösung* is derived from the verb *lösen* ‘solve’ with *-ung* forming an action noun). However, there is no similar morphological pattern for units with an oblique relation. Hence, we expect a stronger tendency towards univerbation with oblique relations because they have a more accessible interpretation as a morphological unit (a compound) and at least a similar productive model construction in government compounds.

The univerbation of individual N + V units also involves very long-term diachronic processes of lexicalisation (see Section 2.2.2). While the individual lexicalisations are likely driven by the prototypicality effects described here, individual units might have progressed further than others on the lexicalisation path. Furthermore, when the compositional meaning of individual N + V units becomes less accessible, univerbation might be favoured due to a facilitated emergence of a holistic (semantically incorporated) conceptual semantics of the unit. Also, units with semantically weak or generic verbs like *haben* (‘to have’), *machen* (‘make’), and *fahren* (‘drive’) are expected to undergo univerbation more easily, because the verbs only denote a specific concept together with the noun. As philological investigations into the fate and semantics of each individual N + V unit are not feasible due to their sheer number, we will capture such individual tendencies numerically by comparing the frequencies of the units with or without univerbation in current usage (collexeme analysis).

The presence of a linking element cannot be conceived of as a causal influencing factor, but rather an additional indicator of compound status. Since linking elements are not paradigmatic in N + V units realised syntactically, its presence is expected in cases where the unit is used as a true N + N compound.

Finally, individual speakers should be expected to have individual tendencies due to the variance in their input and their compliance with normative advice. While individual variation can rarely be controlled in corpus studies due to the lack of metadata identifying individual writers, it should be controlled and/or analysed in behavioural experiments.

At any rate, under a probabilistic usage-based view of language, all these factors are expected to influence univerbation only gradually. Even in cases where all factors favour a realisation with univerbation, writers might sometimes spell it without univerbation and vice versa. However, we expect such

cases to be rarely found in usage data if the hypotheses put forward here correctly describe reality.

As a preliminary step, the basis for any empirical look at N + V units and their spelling has to be a data-driven assessment of which such units exist, how strongly they alternate, and what their item-specific tendencies are, i. e., how clearly they tend to be spelled as one word or two words. Therefore, Section 3 begins with such an assessment.

### 3 Analysing the usage of noun-verb units

In this section, we apply two quantitative methods to analyse the univerbation of N + V units using corpus data. We motivate our choice of corpus and describe the sampling and annotation procedure in Section 3.1. We perform exploratory analysis using association measures in Section 3.2 in order to gauge the individual tendencies of N + V units to incorporate and undergo univerbation in written language usage. The tendencies calculated here will also be used as a covariate in the experiment reported in Section 4. Finally, the results of estimating the parameters of a multilevel model explaining the variation in the univerbation of N + V units are reported in Section 3.3.

#### 3.1 Choice of corpus, sampling, and annotation

As a first step, we adopted a data-driven approach in order to find close to all N + V units in contemporary written usage. In a second step, we counted their occurrences in compound and disjunct spelling in the relevant morphosyntactic contexts enumerated in Section 2.2.3: fully nominalised as the heads of noun phrases, in *am* progressives, as participles in analytical verb forms, and as infinitives in a range of verbal constructions.

Clearly, a large corpus with rich morphological and morphosyntactic annotations containing texts written in a broad variety of registers and styles (including ones written under low normative pressure) was required. We chose the DECOW16B corpus (Schäfer & Bildhauer 2012) because it fulfils all the aforementioned criteria.<sup>25</sup> Much like the SketchEngine corpora (Kilgarriff et al. 2014), the COW corpora contain web documents from recent years. However, the German DECOW (containing 20.5 billion tokens in 808 million sentences and 17.1 million documents) offers a much wider range of annotations compared to SketchEngine corpora, including morphological annotations and several levels of syntactic annotation (dependencies

<sup>25</sup> <https://www.webcorpora.org>

and topological parses). For our purpose, the fully internal analysis of nominal compounds described in Schäfer & Pankratz (2018) was particularly of interest. It allows for corpus searches of roots within nominal compounds. For example, we could query compounds with a deverbal head such as *Zeitnehmen* ('time taking').

The list of actually occurring N + V units was obtained by querying for compounds with a nominal non-head and a deverbal head.<sup>26</sup> The rationale behind this approach is that any N + V unit of interest should occur at least once in compound spelling as a fully nominalised compound. Since this step relied on automatic annotation already available in the corpus, the results contained erroneous hits which we removed manually. The resulting list contained 819 N + V units.<sup>27</sup>

In the second step, we created lists of all relevant inflectional forms of the verb in each N + V unit and used these to query all possible compound and separate spellings (including variance in capitalisation) of each of the 819 N + V unit types. In total, 28,665 queries were executed to create the final data set used here, a number which clearly demonstrates the necessity of script-based corpus access in data-driven methods. The queries were matched by 958,118 compound spellings and 1,288,768 separate spellings, which results in a total sample size of 2,246,886 tokens.

For each N + V unit in the sample, the following variables were annotated automatically: (i) the verb lemma, (ii) the noun lemma, (iii) whether a linking element is used in the use as a full noun, (iv) the overall frequency in the corpus. Additionally, we manually coded all 819 N + V units for the relation holding between the verb and the noun. The codes used in clear-cut cases were *Argument* (441 units) and *Oblique* (286 units). For 92 units, both relations were conceivable, and those cases were coded as *Undetermined*. This class is illustrated by *Daumenlutschen* ('thumb sucking'), which could correspond to the paraphrase either in (13a) or in (13b).

- (13) a. [den Daumen]<sub>NP<sub>Acc</sub></sub> lutschen  
           the thumb suck  
       b. [am Daumen]<sub>pp</sub> lutschen  
           on the thumb suck

<sup>26</sup> See the scripts available under the following DOI for concrete queries and further details:  
 TO BE INCLUDED IN THE ACCEPTED VERSION.

<sup>27</sup> Notice that three highly frequent N + V units were excluded because they could be considered outliers, as they have fully undergone lexicalisation and are virtually always used in compound spelling. They are *Teilnehmen* 'to take part', *Maßnehmen* 'take measure', and *Teilhaben* 'have part' (meaning 'to participate').

The data thus obtained were analysed in two ways. First, we report the results of a collexeme analysis in Section 3.2, which quantifies how strongly individual N + V units tend to be written as one word or two words. The association strengths were used as a covariate in the analysis of the experiment reported in Section 4. Second, in Section 3.3 we report a full statistical model of the alternation.

### 3.2 Results 1: Association strengths

In this section, we report an analysis of the item-specific affinities of N + V units towards univertation. The method we use is similar to collocation analysis (Evert 2008 for an overview) and stems from Collostructional Analysis (Stefanowitsch & Gries 2003). More specifically, the method is called *collexeme analysis* (Stefanowitsch & Gries 2009).<sup>28</sup>

Our goal was to quantify how strongly each N + V unit tends towards univertation vis-a-vis all other N + V units. Thus, we need to compare the counts of cases with and without univertation of the unit in question with the total counts for all other N + V units. Such comparisons must be made relative to the overall number of the specific N + V unit as well as the number of all other units. The counts needed for each N + V unit are nicely summarised in a 2×2 contingency table as shown in Table 1.

	Compound spelling	Disjunct spelling
Specific N+V unit	$c_{11}$	$c_{21}$
All other N+V units	$c_{21}$	$c_{22}$

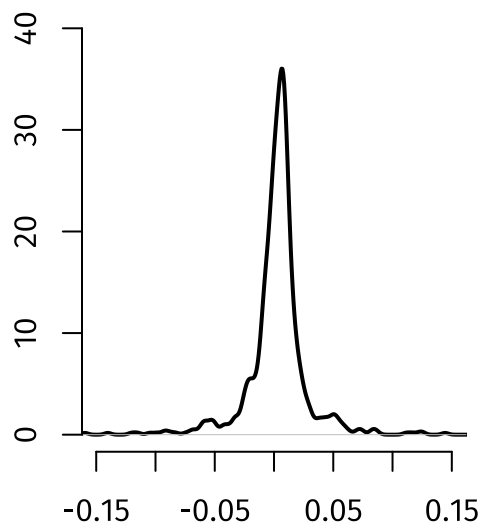
**Table 1:** 2×2 contingency table as used in the calculation of the strengths of the associations of N+V units with univertation.

With these counts, we are able to quantify how strongly the proportion in the first row differ from those in the second row, and there is a range of statistical measures for that. For example, one could use odds ratios or effects strengths from frequentist statistical tests.<sup>29</sup> We chose Cramér's  $\nu$  derived from standard  $\chi^2$  scores ( $\nu = \sqrt{\chi^2/n}$ ). The  $\nu$  measure quantifies for

<sup>28</sup> See also !Schäfer & Pankratz (2018) and !Schäfer (2019) for similar uses.

<sup>29</sup> p-values from frequentist statistical tests are measures of evidence, and therefore not appropriate in such situations (Schmid & Küchenhoff 2013; Küchenhoff & Schmid 2015) although they were used in early Collostructional Analysis. However, even Collostructional Analysis is now often used with measures of effect strength (Gries 2015).

each individual N + V unit how strongly the counts (cells  $c_{11}$  and  $c_{21}$ ) deviate from its counts that we would expect if there were no difference between this unit and all other N + V units (cells  $c_{21}$  and  $c_{22}$ ) with respect to their tendency to univerbate. Since Cramér's  $\nu$  is always in the range between 0 and 1, it allows us to compare analyses where the samples differ. In itself,  $\nu$  does not tell us whether the deviation is negative (for a N + V unit with less than average compound spellings) or positive (for a N + V unit with more than average compound spellings). The information about the direction of the deviation is added by multiplying  $\nu$  with the sign of the upper left cell of the residual table of the  $\chi^2$  test. We calculated the signed  $\nu$  for each of the 819 N + V units. Their distribution is plotted in the form of a density estimate in Figure 1.<sup>30</sup>



**Figure 1:** Density estimate of the distribution of the 819 association scores (across all morphosyntactic conditions).

For the selection of the target stimuli used in the experiment, these association strengths are important, because they encode the effect of the individual N + V units independently of the context. To illustrate how the data analysis allows for a selection of N + V units based on their affinity towards univerbation, we show the top ten units with the highest negative and highest positive association in Table 2. The tables illustrate that units with

<sup>30</sup> As expected, it approximates a scaled symmetric  $\chi^2$  distribution with  $df = 1$  squashed between -1 and 1.

the strongest tendencies against universion are predominantly ones with an argument relation. The ones which most strongly favour universion are mostly ones with an oblique relation or an ambiguous relation. This is in line with our argumentation from Section 2. The ten items with the least clear tendency in either direction are shown in Table 3. They mostly come with an argument relation.

V+N Unit	Assoc.	Rel.	V+N Unit	Assoc.	Rel.
Radfahren	0.190	Undet.	Gedankenmachen	-0.160	Argument
Computerspielen	0.144	Oblique	Geldverdienen	-0.140	Argument
Zeitreisen	0.125	Oblique	Rechtgeben	-0.120	Argument
Skifahren	0.123	Oblique	Spaßhaben	-0.115	Argument
Autofahren	0.117	Undet.	Rechthaben	-0.105	Argument
Probefahren	0.111	Oblique	Kinderhaben	-0.099	Argument
Bogenschießen	0.087	Undet.	Zeitnehmen	-0.093	Argument
Schiffahren	0.085	Undet.	Auftraggeben	-0.092	Argument
Windsurfen	0.084	Oblique	Fehlermachen	-0.088	Argument
Bergsteigen	0.082	Oblique	Urlaubmachen	-0.083	Argument

**Table 2:** Top ten N+V units with a strong tendency for universion (left panel) and top ten N+V units with a strong tendency against universion (right panel).

N+V Unit	Assoc.	Rel.
Autowaschen	0.009	Argument
Zigarettenrauchen	0.007	Argument
Haarewaschen	0.005	Argument
Notenlesen	0.003	Argument
Golfspielen	0.001	Argument
Haarschneiden	-0.007	Argument
Wasserholen	-0.008	Argument
Feuermachen	-0.009	Argument
Blutabnehmen	-0.009	Argument
Schlangestehen	-0.010	Oblique

**Table 3:** Top ten N+V units without any tendency for or against universion.

Among the units with an argument relation, it is difficult to tell based on native-speaker intuition why the ones in Table 3 should have no preference and the ones in Table 2 (right panel) should resist universion.

This goes to show that, while we can model the tendencies to some extent using linguistic features, there are obvious item-specific effects which should be taken seriously from a theoretical perspective (which is why Collostructional Analysis was introduced), and which must be accounted for in behavioural experiments. We turn to such an experiment in Section 4. However, we first report a full statistical model of the influencing factors derived from the corpus data in Section 3.3.

### 3.3 Results 2: Multilevel model

In this section, we present the parameter estimates (and predictions of conditional modes) for a binomial multilevel model (or generalised linear mixed model, GLMM) which models the relevant factors influencing writers' choice of the compound and the separate spelling.<sup>31</sup> The results of the method used in Section 3.2 and the GLMM presented here converge. However, the GLMM has a more standard interpretation and allows for finer-grained data analysis. Also, it has long been accepted that combining several methods strengthens the analysis when the results converge (e. g., [Arppe & Järvikivi 2007](#)).

Given the grand total of 2,246,886 observations in the sample (see Section 3.1), we will completely refrain from an interpretation of the GLMM in terms of frequentist inferential statistics. For samples of such magnitude in data-driven approaches, frequentist significance tests are the wrong tool. Therefore, we provide standard likelihood ratio confidence intervals for parameter estimates and prediction intervals for conditional modes as an approximate measure quantifying the precision of the parameter estimates and predictions. The models we specify reflect theoretically motivated decisions, and we therefore reject all types of model selection by means of step-up or step-down procedures.

As argued in Section 2.2, we expect the probability of the univerbation of N + V units to depend on the morphosyntactic context, the relation holding between the verb and the noun, the presence of absence of a linking element in the nominal compound (as a marker of a stronger lexicalisation) and on the specific N + V unit (a lexical tendency). Accordingly, the response variable was chosen to be the proportion of compound spellings among all the spellings of the N + V unit. In the input data provided to the estimator, the response variable was thus a vector of 819 proportions,

<sup>31</sup> See [Schäfer \(2020\)](#) for an overview of the method and our philosophy in modelling.



one for each N + V unit.<sup>32</sup> We specified four regressors. The only first-level (or observation-level) fixed effect regressor is the morphosyntactic context (a four-way categorical variable). We decided to break down the possible morphosyntactic contexts into four types:

- i. adjunct *zu* infinitives (see example 2e),
- ii. participles as complements of auxiliaries (see example 2c),
- iii. the so-called *am* progressive (see example 2f),
- iv. full NPs (see example 2h).

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The constructions with the infinitive (i) and the participle (ii) represent two prototypically syntactic constructions as the verb from the N + V is part of a verbal syntagma. The NP context (iv) is most prototypically nominal, especially since we only used NPs with a determiner. More precisely, we only used NPs with definite determiners cliticised to a preposition (*beim* ‘at the’, *zum* ‘to the’, etc.). This decision was made in order to allow for a comparison of these full nominalisations and the so-called *am* progressive (iii). The progressive is formed with the copula/auxiliary *sein* ‘to be’, the variant of the preposition *an* with the cliticised definite article *am* ‘at the’ and the infinitive. While it developed out of a construction with a copula and a plain NP within a PP, and it is formally identical to cases with the normal NPs in (iv), it is often assumed to be a verbal construction expressing progressive meaning. Including NPs in this specific form along with this emerging progressive construction allows us to assess whether the hypothesised verbal semantics of the progressive makes the construction more verbal, leading to a weaker tendency towards univerbations compared to regular NPs. To summarize, we expect N + V units in infinitives and participles (prototypically verbal) to have a weak tendency and N + V units in full NPs (prototypically nominal) to have a strong tendency towards univerbation in line with the argumentation from Section 2.2. We have no prediction for the progressive as we are unsure whether it has truly developed into a verbal construction.

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As there is a huge number of 819 N + V units, the lexical indicator variable for the individual N + V unit should not be used as a fixed effect (Gel-

<sup>32</sup> Binomial models can be specified in this manner (Zuur et al. 2009: 245–260). In the estimation of such models, the influence of each proportion is weighted according to the number of cases observed to calculate it. Without the weighting, highly frequent observed proportions would have too small an influence on the estimation, and infrequent ones would have an inappropriately high influence. In the case at hand, such a model on proportion data is also a convenient way of getting around the practical difficulties of estimating a model on the raw 2,246,886 observations.

man & Hill 2006: 244–247, Schäfer 2020). We specified a generalised linear mixed model with the N + V unit variable as a random effect. The variables encoding the internal relation and the presence/absence of a linking element are nested inside the levels of the random effect, and they are therefore treated as second-level fixed effects in a multilevel model. In R notation, the specification is shown in (14).<sup>33</sup>

(14)  $\text{Univerbation} \sim (1|\text{NVUnit}) + \text{Context} + \text{Relation} + \text{Link}$

	Estimate	CI low	CI high
(Intercept)	-4.787	2.000	2.218
Context = Participle	1.054	-5.020	-4.555
Context = NP	3.886	0.976	1.133
Context = Progressive	4.907	3.815	3.959
Relation = Undetermined	1.339	4.801	5.015
Relation = Oblique	3.132	0.862	1.816
Link = Yes	0.361	2.808	3.456

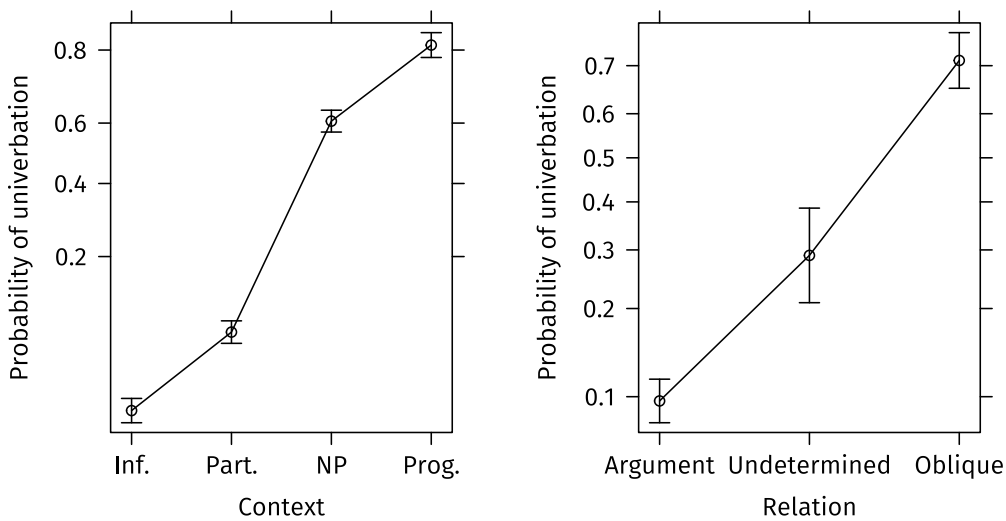
**Table 4:** Coefficient table for the binomial GLMM modelling the corpus data with 95% profile likelihood ratio confidence intervals. The horizontal line separates first-level and second-level effects. Weighting was used to account for the bias in models on proportion data. Random effect for N+V lemma: Intercept = 4.430, sd = 2.105. The intercepts model the fixed effects Relation = Argument and Link = No. Nakagawa & Schielzeth’s  $R_m^2 = 0.577$  and  $R_c^2 = 0.999$ .

The estimated parameters of the model are given in Table 4. Additionally, effect plots for *Context* and *Relation* are given in Figure 2.<sup>34</sup> As expected, the prototypically verbal contexts (infinitives and participles) are associated with a low probability of compound spelling (the infinitive is on the intercept, which is estimated at  $-4.787$ , and participles have a coefficient of  $1.054$ ). NPs and progressives as prototypically nominal contexts

<sup>33</sup> See Appendix A for a precise specification in mathematical notation.

<sup>34</sup> Effect plots for binomial GLM(M)s (Fox & Weisberg 2018) plot the probability of the outcome across values of a regressor assuming default values for all other regressors. While model coefficients in binomial (and other) models have no direct interpretation in terms of probability, effect plots allow a more intuitive interpretation in terms of changes in probability.

clearly favour compound spelling (coefficients of 3.886 and 4.907, respectively). Both the coefficients and the effect plot (right panel in Figure 2) show a low probability of compound spelling when an argument relation holds between the verb and the noun (on the intercept), and a high probability when the relation is oblique (coefficient 3.132). The undetermined cases are in between the two clear-cut cases (coefficient 1.339). The presence of a linking element in fully nominalised compounds favours compound spelling only slightly (coefficient 0.361).

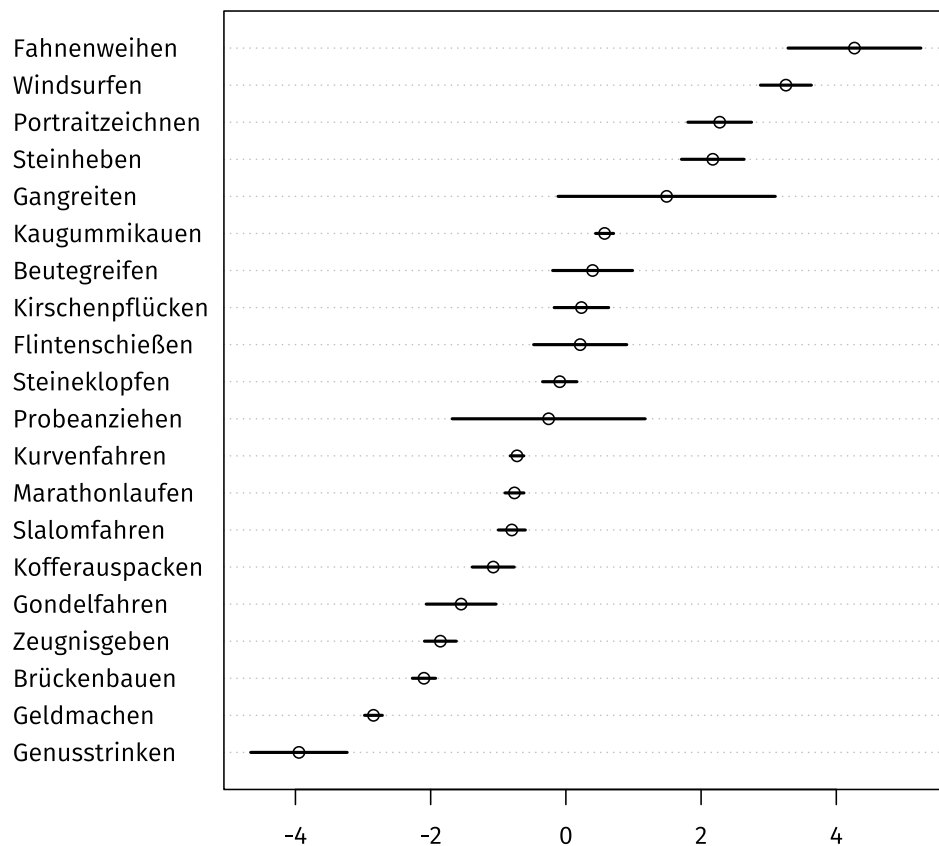


**Figure 2:** Effect plots for the regressor encoding the morphosyntactic context of the N+V unit and the regressor encoding the syntactic relation within the N+V unit in the GLMM modelling the corpus data.

Given the narrow confidence intervals and the high marginal measure of determination  $R_m^2 = 0.577$ , we consider the hypotheses regarding fixed effects as well corroborated by the data, especially the effects of the context and the internal relation. The differences between specific N + V units already shown in Section 3.2 show up in the model as the residual variance in the random effects (in the form of the conditional modes).<sup>35</sup> The conditional modes are centred around a second-level intercept of 4.430 with a standard deviation of 2.105. The relatively high standard deviation is a sign that there is considerable variation across the individual N + V units.

<sup>35</sup> On a technical note, this is only the component of the variance which is not explained by the second-level effects.

Furthermore, the conditional  $R_c^2$  is as high as 0.999. This is commonly interpreted as saying that the fixed effects and the idiosyncratic effect of concrete N + V units almost fully explain the variance in the data. A random selection of 20 conditional modes, which illustrates the relevance of lexical idiosyncrasies through obvious differences with mostly very narrow prediction intervals, is shown in Figure 3.



**Figure 3:** A random selection of conditional modes with 95% prediction intervals for the levels of the random effect in the GLMM modelling the corpus data.

The individual N + V unit thus plays a major role in writers' tendency to univerbate N + V units, which conforms the results from Section 3.2. The results obtained from that method will be used to predict participants' behaviour in the controlled experiment reported in Section 4.

## 4 Elicited production of noun-verb units

In this section, we corroborate the findings from Section 3 in a controlled experiment. We describe the rationale behind the experiment, the methods used, the design, and the group of participants in Section 4.1. Section 4.2 reports the results descriptively and in the form of a generalised linear mixed model.

### 4.1 Design and participants

The goal of the experiment was to corroborate the findings from the corpus study and to test whether writers' behaviour under controlled experimental conditions is similar to the behaviour of writers under uncontrolled circumstances as found in corpora. We used pre-recorded auditory stimuli in order to elicit spellings of given N + V units. The stimuli were chosen based on theoretically motivated criteria and the information about item-specific tendencies obtained from the exploratory part of the corpus study in Section 3.2. We constructed eight sentences instantiating the four contexts described in Section 3.3. For each of the four contexts, we chose one N + V unit with a high and one with a low attraction strength according to the analysis of the usage data.<sup>36</sup> The sentences were constructed in a ways such that all N + V units were the predicate of a subordinate clause. This consistently ensured verb-last constituent order and avoided interfering verb-second effects, which are typical of independent sentences in German. The stimuli with full glosses are given in Appendix C. An overview of the item design is shown in Table 5, where each line represents the features of one of the eight items. Since the relation follows the high/low attraction

<sup>36</sup> Given the overall constraints on the choice of the items, “low” and “high” had to be interpreted as quite relative terms. However, we made sure that all low attractions scores are lower than zero and all high attraction scores are greater than zero. Also, for each context, the low and the high attraction score differ by at least 0.05. In the statistical analysis of the experimental data, we used the actual attraction strength as a covariate instead of a binary factor, which compensates for problems in the choice of stimuli.

dichotomy perfectly, we specify it in the table, but we did not include it in the statistical analysis to stay clear of problems with collinearity.

Context	N+V unit	Attr. score	Bin. attr.	Relation
Infinitive	Platzmachen	-0.052	Low	Argument
	Seilspringen	0.011	High	Oblique
Participle	Mutmachen	-0.069	Low	Argument
	Probehören	0.055	High	Oblique
Progressive	Teetrinken	-0.037	Low	Argument
	Bogenschießen	0.087	High	Oblique
NP	Spaßhaben	-0.115	Low	Argument
	Bergsteigen	0.082	High	Oblique

**Table 5:** Items from the experiment, chosen by context and attraction score.

We added 32 fillers, resulting in a total of forty sentences being read to the participants.<sup>37</sup> Of the forty sentences, twenty (including the target items) had to be written down by the participants. The order of the target items was randomised, but it was ensured that there were at least three sentences in between two target stimuli. There were nine distractors in the form of yes-no questions related to random sentences previously heard by the participants.

In total, 61 participants took part in the experiment. All of them were first-semester students of German Language and Literature at Freie Universität Berlin. They were between 18 and 44 years old with a median age of 22 years. There were two separate groups (32 and 29 participants, respectively), and the randomisation of the order of stimuli was different between the two groups.

## 4.2 Results

In this section, we report the parameter estimates of a GLMM with additional control for individual participants in the form of a random effect. Instead of using a grouping variable for the N + V units, we included their association strengths directly in the model. The model specification in R notation is given in (15). Appendix B provides the specification mathematical notation. The coefficient estimates for the GLMM are reported in Table 6.

<sup>37</sup> Of the forty fillers, six were actually items from an unrelated experiment.

$$(15) \quad \text{Univerbation} \sim (1|\text{Participant}) + \text{Attraction} + \text{Context}$$

	Estimate	CI low	CI high
(Intercept)	-4.026	-5.533	-2.851
Attraction	48.740	34.657	73.466
Context = Participle	1.126	-0.375	2.574
Context = Progressive	6.224	4.691	8.184
Context = NP	8.166	5.978	11.512

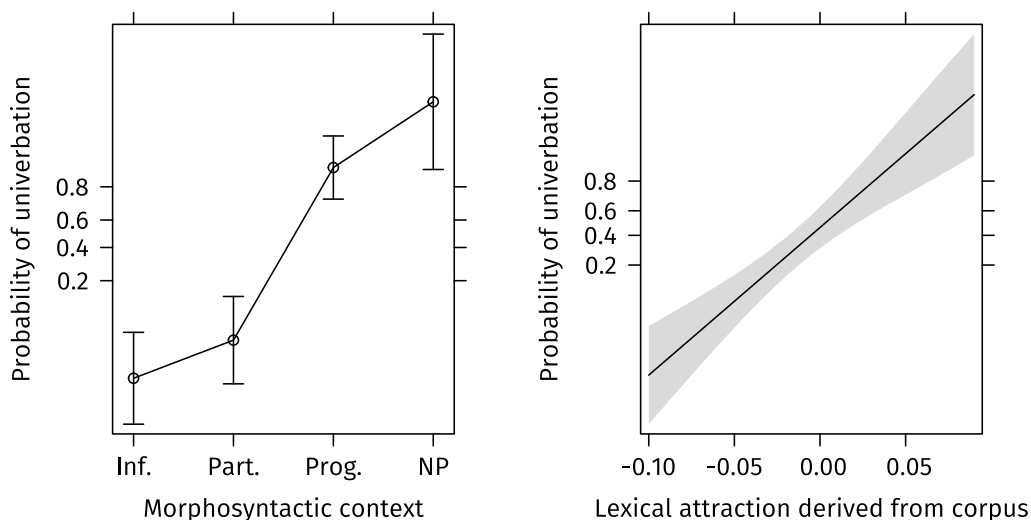
**Table 6:** Coefficient table for the GLMM modelling the experiment data with 95% confidence intervals. Nakagawa & Schielzeth's  $R_m^2 = 0.803$  and  $R_c^2 = 0.896$ . Random effect for participant: Intercept = 2.966, sd = 1.722 The intercept models the fixed effect Context = Infinitive as well as Attraction = 0.

There is some variation between writers as captured in the standard deviation of the conditional modes (1.722), but the small difference between the marginal  $R^2$  (0.803) and the conditional  $R^2$  (0.896) suggests that speaker variation does not explain much of the variance in the data. This corroborates our assumption from Section 1 that the phenomenon is not about individuals mastering the norm to different degrees or having different preferences when it comes to univerbation. Instead, the major deciding factors are the ones predicted by our theoretical model.

The coefficients indicate that the attraction strength derived from the corpus is positively correlated with the participants' tendency to univerbate (48.740). There seems to be no evidence that the participle has a different effect than the infinitive (which is on the intercept) given the large confidence interval  $[-0.375..2.574]$ . On the other hand, progressives (6.224) and NPs (8.166) clearly have a much more positive effect on the probability of univerbation. Again, we do not see evidence for a any difference between NP and progressive contexts given the large and overlapping confidence intervals.

The effect plots in Figure 4 (left panel) provides a visual interpretation of the coefficient table. The prototypically verbal contexts are associated with low probabilities of univerbation, the two prototypically nominal ones with high probabilities of univerbation. Judging by the large and mostly overlapping confidence intervals, there is no support for assuming a substantial difference between participles and infinitives on the one hand and





**Figure 4:** Effect plots for the regressor encoding the morphosyntactic context and the attraction strength as calculated from the corpus in the GLMM modelling the experimental data.

progressives and NPs on the other hand. The attraction scores are neatly correlated with the probability of universion (right panel of Figure 4).

In sum, the experiment supports our theoretically motivated hypotheses, and it corroborates the results from the corpus study. We proceed to a final analysis of the phenomenon at in the light of our findings in Section 5.

## 5 Explaining noun-verb universion

### A Corpus study: full specification of the model

In Section 3.3, the specification of the model was given in R notation as (14), repeated here as (16).

$$(16) \quad \text{Universion} \sim (1|\text{NVUnit}) + \text{Context} + \text{Relation} + \text{Link}$$

This notation blurs the difference between first-level and second-level fixed effects. The model specification is the crucial step in statistical modelling since it encodes the researchers' commitment to a causal mechanism

controlling the phenomenon to be modelled (in this case, writers' mental grammars with respect to the univertation of N + V units). Model specification thus deserves more attention than (16) has to offer. Mathematically and thus more transparently, the model is given in (17). The notation with angled brackets in  $\alpha_{NV_j[i]}$  should be read as "the value of the random effect  $\alpha_{NV}$  for the factor level  $j$ , chosen appropriately for observation  $i$ ."

$$(17) \quad Pr(Univ_i = 1) = \text{logit}^{-1}[\alpha_0 + \alpha_{NV_j[i]} + \vec{\beta}_{Context} \cdot \vec{x}_{Context_i}]$$

The proportion of compound spellings  $Prop_{Comp_i}$  is the logit-transformed sum of the overall intercept  $\alpha_0$ , the random intercept for the  $j$ -th N + V unit  $\alpha_{NV_j[i]}$  (whichever is found in observation  $i$ ) and the dot product of the vector of dummy-coded binary value for the morphosyntactic context  $\vec{x}_{Context_i}$  and the vector of their corresponding regressors  $\vec{\beta}_{Context}$ . Since it is a multilevel model,  $\alpha_{NV}$  has its own linear model, which is given in (18).

$$(18) \quad \alpha_{NV_j} = \gamma_j + \vec{\delta}_{Relation} \cdot \vec{x}_{Relation_j} + \delta_{Link} \cdot x_{Link_j}$$

It is also assumed that 19 holds, i. e., that the random intercepts for individual N + V units are normally distributed.

$$(19) \quad \alpha_{NV} \sim Norm$$

The random effects are assumed to be a normally distributed variable  $\alpha_{NV}$  which is for each N + V unit  $j$  given as the sum of the conditional mode of unit  $i$  (often wrongly called the *random effect* per se), the dot product  $\vec{\delta}_{Relation} \cdot \vec{x}_{Relation_j}$  of the vector of binary variables encoding the relation and the vector of their corresponding coefficients, and finally the product  $\delta_{Link} \cdot x_{Link}$  of the binary variable encoding the presence of a linking element and its coefficient.

## B Experiment: full specification of the model

In this appendix, we provide the mathematical notation of the model specified in Section 4.2 as (15) and repeated here as (20).

$$(20) \quad Univertation \sim (1|Participant) + Attraction + Context$$

The model is specified in the same notation as in Appendix A in (21). The regressor  $x_{Attract_i}$  is numeric (the attraction score), whereas  $\vec{x}_{Context_i}$  is a dummy-coded vector of binary variables.

$$(21) \Pr(Univ_i = 1) = \text{logit}^{-1}[\alpha_0 + \alpha_{part_j[i]} + \beta_{Attract} \cdot x_{Attract_i} + \vec{\beta}_{Context} \cdot \vec{x}_{Context_i}]$$

It is also assumed that 19 holds, i. e., that the random intercepts for individual participants are normally distributed.

$$(22) \alpha_{Participant} \sim Norm$$

## C Sentences used in the experiment

The N + V units are typeset in smallcaps and spelled as separate words. The order of the sentences corresponds to Table 5.

- (23) Lara trat zur Seite, um **Platz** zu **machen**.  
 Lara stepped to the side in order room to make  
 Lara stepped aside to make way.
- (24) Sarah ging auf den Spielplatz, um **Seil** zu **springen**.  
 Sarah went onto the playground in order rope to jump  
 Sarah went to the playground to do some skipping.
- (25) Leon konnte nur deshalb gewinnen, weil Johanna ihm  
 Leon could only therefore win because Johanna him  
**Mut gemacht** hat.  
 courage made has  
 Leon could win only because Johanna encouraged him.
- (26) Maria hat einen Kopfhörer gekauft, nachdem sie ihn **Probe**  
 Maria has a headphone bought after she it test  
**gehört** hatte.  
 listened had  
 Maria bought a headphone after doing a listening test.
- (27) Melanie mag Fußball, weil es ein Sport zum **Spaß** **haben** ist.  
 Melanie likes soccer because it a sport to the fun have is  
 Melanie likes soccer because it's a fun sport.

- (28) Benjamin ruft seinen Freund an, weil er eine Frage zum  
 Benjamin calls his friend on because he a question to the  
**Berg steigen** hat.  
 mountain climbing has  
 Benjamin calls his friend because he has a question about mountain  
 climbing.
- (29) Kim sah sich das Tennisspiel an, solange sie am Tee  
 Kim watched herself the tennis match on while she at the tea  
**trinken** war.  
 drink was  
 Kim watched the tennis match while drinking some tea.
- (30) Simone hört ein Hörbuch, während sie am Bogen schießen  
 Simone listens an audiobook while she at the bow shoot  
 ist.  
 is  
 Simone listened to an audiobook while practicing archery.

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