Towards a treatment of register phenomena in HPSG

Antonio Machicao y Priemer
Humboldt-Universität zu Berlin

Stefan Müller
Humboldt-Universität zu Berlin

Roland Schäfer
Friedrich-Schiller Universität Jena

Felix Bildhauer
Humboldt-Universität zu Berlin

Proceedings of the 29th International Conference on
Head-Driven Phrase Structure Grammar

Online (Nagoya/Tokyo)

Stefan Müller, Elodie Winckel (Editors)

2022

Frankfurt/Main: University Library

pages 86–101

Keywords: HPSG, register variation, probabilistic approach, multi-lingual grammar

Machicao y Priemer, Antonio, Stefan Müller, Roland Schäfer & Felix Bildhauer. 2022. Towards a treatment of register phenomena in HPSG. In Stefan Müller & Elodie Winckel (eds.), *Proceedings of the 29th International Conference on Head-Driven Phrase Structure Grammar, Online (Nagoya/Tokyo)*, 86–101. Frankfurt/Main: University Library. DOI: 10.21248/hpsg.2022.5.

Abstract

In this paper, we deal with register-driven variation from a probabilistic perspective, as proposed in Schäfer, Bildhauer, Pankratz & Müller (2022). We compare two approaches to analyse this variation within HPSG. On the one hand, we consider a multiple-grammars approach and combine it with the architecture proposed in the CoreGram project (Müller, 2015) – discussing its advantages and disadvantages. On the other hand, we take into account a single-grammar approach and argue that it appears to be superior due to its computational efficiency and cognitive plausibility.

1 Introduction

It is not only important what we say when making utterances, but also how we say it. Language users use and recognize a range of *registers* in communicative situations. For instance, people talk differently to a cab driver during a ride, in a job interview, and to their friends in a pub. While there is a research tradition on registers in formal frameworks (e. g., Paolillo, 2000; Bender, 2007; Adger, 2006; Asadpour et al., 2022), there is probably no such thing as a taxonomy of registers for a given language that most researchers would agree on (let alone a cross-linguistic inventory of registers, see Schäfer, Bildhauer, Pankratz & Müller 2022). Considerable confusion exists regarding the delineation of registers and related categories such as style and genre. Furthermore, the most likely fuzzy boundaries between registers make it notoriously difficult to even agree on necessary and/or sufficient conditions (such as the occurrence of particular linguistic features) for category membership (Biber & Conrad 2009; see Argamon 2019). However, it is obvious that all parts of the linguistic system that have been studied in HPSG play a role in modelling register phenomena (Bender, 2007, 354). For instance, in phonology and morphology: whether reduced forms of words are used or not as in (1); in the lexicon connecting phonology, syntax, semantics: whether formal or less formal vocabulary is used as in (2); in syntax: whether complex and elaborated relative clauses are used or not (cf. Asadpour et al., 2022); in semantics: whether we use a precise or imprecise expression as in (3).

(1) Ich { *habe es* / *hab's*} gekauft.
I have it have.it bought
'I have bought it.'

[†]We want to thank the following colleagues for their valuable comments: Giuseppe Varaschin, Viola Schmitt, and the participants of the HPSG Conference 2022 – specially Bob Borsley, Frank Richter, Jakob Maché, Nurit Melnik, Manfred Sailer and three anonymous reviewers. All remaining errors are ours. This paper was partly funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – SFB 1412, 416591334, Project A04.

(2) Meine Frau ist { *Polizistin* / *Bulle* }.
my wife is policewoman cop
'My wife is a policewoman.'

(3) I will arrive at {*3:32* / *half past 3*}. (cf. Solt, 2015)

In a data-driven analysis to be reported elsewhere (Schäfer, Bildhauer, Pankratz & Müller, 2022), we have used Bayesian generative models (Latent Dirichlet Allocation, Blei et al. 2003) to infer potential registers (instantiated in clusters of documents) from a large corpus of German based on the distribution of linguistic signs in the documents. While superficially similar to work by Douglas Biber (e.g., Biber 1988, 1995), our approach differs significantly from Biber's. It is fully probabilistic and allows for many-to-many associations between linguistic signs, registers, and documents, and it does not rely on available a priori register taxonomies. In a further step of manual annotation, we managed to reliably identify situational-functional parameters such as a higher level of education, proximity, or interactivity for the potential registers. We find, for example, that some registers are associated with a high probability of occurrences of adverbs, certain tense forms, or more complex phenomena like passives and clausal pre-fields.

In this paper, we discuss and provide an implementation of such findings in a formal grammar – an issue that has been largely neglected in formal theories of grammar (e. g. Labov, 1969; Guy, 1996; Hudson, 1997; Bender, 2001, 2007; Fasold & Preston, 2007). HPSG is highly suitable for the task at hand because its multi-level architecture allows us to formulate constraints on all levels of linguistic description. Furthermore, by virtue of constraint underspecification, it enables us to add register information to more general grammatical constraints that are assumed for independent reasons.

From the perspective of both grammar theory and psycholinguistics, one overarching question is how variation in grammar (including register variation) is encoded in speakers' grammars, and how speakers use it (cf. Lüdeling et al., 2022). Different (more or less explicit) answers to the variation issue have been given in various frameworks (cf. Paolillo, 2000; Adger, 2006; Jackendoff & Audring, 2020 for examples in HPSG, Minimalism, and Parallel Architecture, respectively) and with respect to diverse sub-components of grammar and regarding extra-grammatical components. One option is to assume that speakers deal with different registers by using a set of distinct grammars or a single grammar with a separate module encoding variation (Yang, 2002; Adger, 2006). In contrast, it is also conceivable that speakers use a single grammar with all information about the variation encoded in it (Paolillo, 2000; Bender, 2001, 2007; Pierrehumbert, 2008; Hilpert, 2013). While it cannot be known whether such questions can ultimately be answered based on empirical evidence available today, the goal of this paper is to explore ways in which either approach could be implemented in HPSG.

It should be noted that using different grammars for different registers is technically reminiscent of the approach presented in Søgaard & Haugereid (2007), who propose a grammar for Scandinavian containing subgrammars for Danish, Norwegian and Swedish. The authors use a LANGUAGE feature that serves to identify the language (or languages) of a linguistic object. However, such a model of different languages is not necessarily related to cognitive reality, simply because many speakers only speak one of the three languages. Register variation is fundamentally different in this respect since competent speakers are able to understand and produce utterances in various registers.

In this paper, we compare two potential approaches to register modelling in HPSG, one assuming multiple grammars for multiple registers (Section 2), and one assuming only one grammar including information about several registers (Section 3).

2 Multiple grammars for multiple registers

As pointed out in the introduction, speakers/hearers are able to use and detect various registers. This is reminiscent of multilingualism, and hence an obvious route to take is to have a look at multi-lingual grammar engineering projects within the HPSG framework and their potential to be adapted to modelling register variation.

A register-aware grammar does not need to distinguish between the *grammaticality* of utterances in different situations because even register-mismatched utterances are grammatical. It should rather model their *adequacy* in these situations. Judgements of register adequacy are scalar (not binary like grammaticality judgements), and they have therefore been analysed as felicity conditions (cf. Paolillo, 2000; Bender, 2007; Asadpour et al., 2022). An utterance that can be used in a rather informal register – let's call it Register I – can also be used in a rather formal register – let's call it Register F. This utterance does not need to be ruled out by the grammar, but its use is simply less adequate. It might violate felicity conditions imposed by the context, but it can be used and will be understood in a formal situation. For instance, (4)[1] shows an utterance from Joschka Fischer, a member of the German parliament in 1984, in a parliament session. While the word *Arschloch* 'asshole' belongs to Register I, other elements in the utterance (e.g. *mit Verlaub* 'with respect') clearly signal Register F, i.e. leading to a so-called register clash (cf. Jackendoff & Audring, 2020, 248).

(4) Herr Präsident, Sie sind ein Arschloch, mit Verlaub!
'With respect, Mr. President, you are an asshole!'

[1] https://www.sueddeutsche.de/politik/parlamentarisches-schimpfbuch-auf-den-strich-gehe-ich-nicht-1.389241

In a multiple-grammars approach, the individual grammars (i. e., one for each register) interact with each other, allowing elements of one grammar (word, syntactic rules, etc.) to be combined with elements of another grammar. That is, every grammar needs to share constraints on linguistic signs with the others. The predictions to be made by such a system should not be (as mentioned already) grammaticality decisions but rather quantifications of the *probability of utterances in a given register*. However, cross-linguistic grammar implementation could provide a general framework for an implementation of register grammars in HPSG.

There are two main approaches to multi-lingual grammar engineering within HPSG: the Grammar Matrix (cf. Bender et al., 2002; Flickinger et al., 2000; Flickinger, 2000)[2] and the CoreGram project (Müller, 2015). Due to its explicit goal to implement grammars that are organised using interacting sets of constraints, in this paper we concentrate on the architecture proposed in the CoreGram project. Theoretically at least, this architecture is well suited to our needs, since such sets could also be used to model register phenomena in the context of a multiple-grammars approach.

Müller (2015, 2014) explains the general CoreGram approach with respect to German and Dutch grammars as follows. German and Dutch are rather similar: they are both SOV languages, both are V2 languages, both have verbal complexes, and they share many other common properties. The argument structure constructions and linking are very similar (see Davis et al. 2021 on linking). Of course, the lexical items and the pronunciation are different, there are differences in the specific way the verbal complexes are organised in Dutch and (Standard) German, and so on (compare the work of Bouma & van Noord 1998 and Hinrichs & Nakazawa 1994; Kiss 1995; Meurers 2000; Müller 2013).

The organisation of constraint sets is illustrated in Figure 1. All shared constraints between the two grammars (e. g. constraints dealing with argument structure, verb-second order, SOV constituent order, verbal complexes, and the Head-Filler Schema) are in Set 3. Those constraints that apply only to German are in Set 1 and those particular to Dutch in Set 2. That is, Set 1 and 2 contain (among other things) the lexicons of the respective languages.

When we add a third related language such as Danish, the picture gets more complex. German, Dutch and Danish share the property of being V2 languages, and they share linking and argument structure constraints. Danish is an SVO language, and it does not have verbal complexes. Hence, all constraints that are specific to Danish are in Set 6 in Figure 2. Obviously, when other SVO languages like English and French are added, new constraint sets will emerge.

It is worth mentioning that although Figure 2 looks like an inheritance

[2]The Grammar Matrix approach could also work to model the multiple-grammars as well as the single-grammar approach.

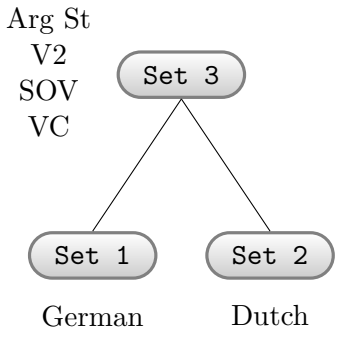

Figure 1: Shared properties of German and Dutch

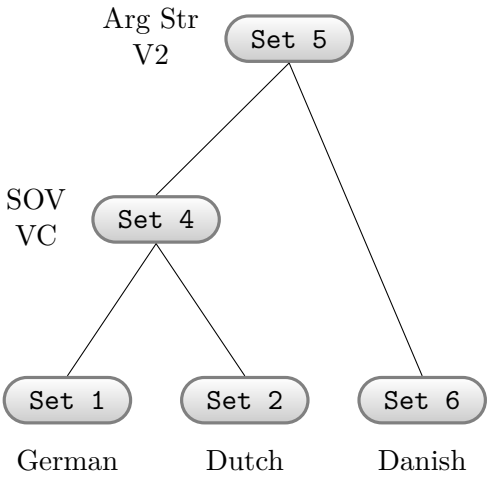

Figure 2: Shared Properties of German, Dutch, and Danish

hierarchy, it is not. It is a depiction of inclusion relations, where more specific sets include the more general sets. That is, Set 4 includes Set 5, and Set 2 includes Set 4. Due to this property, the Dutch grammar (in Figure 2) needs to include Set 2 only since it also includes the constraints specified in Set 4 and Set 5.

Now, this approach could also be applied in a top-down way to model register phenomena. The most general constraint set would be Set 1 in Figure 3, which represents a general grammar of German – as illustrated in Figure 2. There would be (at least) two further sets, let's call them Set 1-F and Set 1-I, for two different registers: a rather formal and a rather informal register. These sets include all constraints from Set 1, the general grammar of German, and specific constraints related to their particular register type.[3]

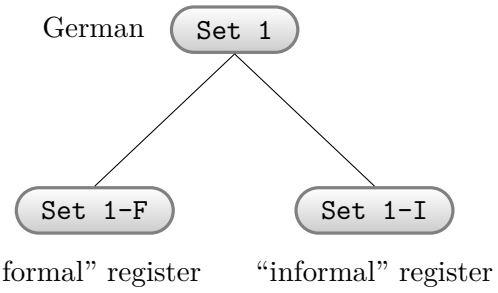

Figure 3: Modelling two registers of German

For example, certain words, aspects of meaning, constructions, or constraints could be associated with either of the two registers. For instance, the German word *Kohle* (lit. 'coal') can be used referring to 'money' in informal communication (cf. *dough* in English). Therefore, one might assign it to Set 1-I, that is, to the informal register. Alternatively, the meaning of the word *Kohle* could be 'coal_or_money' in Set 1, and it would be further constrained such that the meaning 'money' is ruled out (or rather be assigned a very low probability, see below) in Set 1-F but not in Set 1-I.

One main aspect of register variation that has to be taken into account is that the occurrence of register-sensitive linguistic features is usually not a matter of all-or-nothing (see e.g. Biber & Conrad, 2009, 53–54 as discussed in Section 1). Therefore, our approach – in line with the assumptions underlying our exploratory Bayesian analysis (cf. Schäfer, Bildhauer, Pankratz & Müller, 2022) – assumes a *probability distribution* for linguistic features spe-

[3]As mentioned in Section 1, there is no agreement within the linguistic community with respect to an inventory or taxonomy of existing registers. We work with registers that have been identified by analysing the distributions of linguistic signs in corpus data, and which have been associated with situational-functional properties through manual annotation (following Schäfer, Bildhauer, Pankratz & Müller, 2022). In the present paper, concrete registers are only chosen for illustrative purposes since we only discuss fundamental problems of formal implementations of register grammars.

cific to each register. This can be captured in HPSG by attaching weights or probabilities to register-sensitive entities, including lexemes, inflectional and derivational lexical rules and syntactic schemata.

For instance, in the informal register (Set 1-I), the word *Kohle* 'money' could have higher probability than the more neutral word *Geld* 'money', and *Geld* could have a higher probability than the word *Kohle* 'money' in the formal register (Set 1-F). When two or more linguistic objects are combined, the weight/probability of the mother is computed from the weight/probability of the daughters and the register value of the schema/rule that licenses the combination. Unfortunately, the mathematics behind probabilistic HPSG is not completely worked out yet, but there are promising initial ideas (Brew, 1995; Abney, 1997; Miyao & Tsujii, 2008; Guzmán Naranjo, 2015). It is worth noting that this approach understands the usage component of language as a part of the grammar, rather than treating it as a factor external to language – in line with usage-based approaches (contra e.g. Newmeyer, 2003).

The approach described above also works for syntactic phenomena. For instance, in our identification of registers in the data-driven analysis, the complexity of constituents in clause initial position (in the so-called *Vorfeld*) turned out to be a good indicator of registers requiring an elevated level of education. Since German is a Verb Second language, any constituent can occupy the Vorfeld, including full clauses (5c). The syntax of German contains a Filler-Head Schema that is not restrictive as far as the filler daughter is concerned. The actual filler is determined by what is missing in the rest of the sentence. It can be an NP (5a), a PP, an adverb (5b), a verbal projection (5c), or one of many other types of constituents.

(5) a. [Den Nachbarn]$_i$ hat Tina gestern $\__i$ gefragt, ob
the.ACC neighbour.ACC has Tina yesterday asked whether
er sie kennt.
he her knows

b. Gestern$_i$ hat Tina $\__i$ den Nachbarn gefragt, ob er sie
yesterday has Tina the neighbour asked whether he her
kennt.
knows

c. [Ob er sie kennt]$_i$, hat Tina gestern den Nachbarn
whether he her knows has Tina yesterday the neighbour
gefragt $\__i$.
asked

'Yesterday, Tina has asked the neighbour whether he knows her.'

This is covered by the fact that the only constraint on the filler daughter that is specified in the Filler-Head Schema (cf. (6)) is that the LOCAL value of the filler has to match the element in SLASH.

(6) Filler-Head Schema according to Müller (2013, 169):

head-filler-phrase ⇒

$$\begin{bmatrix} \textsc{nonloc}|\textsc{slash} & \langle\rangle \\ \textsc{head-dtr}|\textsc{synsem} & \begin{bmatrix} \textsc{loc}|\textsc{cat} & \begin{bmatrix} \textsc{head} & \begin{bmatrix} \textit{verb} \\ \textsc{vform} & \textit{fin} \\ \textsc{initial} & + \end{bmatrix} \\ \textsc{subcat} & \langle\rangle \end{bmatrix} \\ \textsc{nonloc}|\textsc{slash} & \left\langle \boxed{1} \right\rangle \end{bmatrix} \\ \textsc{non-head-dtrs} & \left\langle \begin{bmatrix} \textsc{synsem} & \begin{bmatrix} \textsc{loc} & \boxed{1} \\ \textsc{nonloc}|\textsc{slash} & \langle\rangle \end{bmatrix} \end{bmatrix} \right\rangle \end{bmatrix}$$

We can now use additional constraints on *head-filler-phrase* to encode register knowledge. Assume that we are currently analysing a sentence using a set of constraints that corresponds to a rather formal register (e.g. Set 1-F above). If we see a *head-filler-phrase* with a filler-daughter that is a finite verbal projection (a clause), then we know that within the formal register at hand, its probability of occurrence is (relatively) high. For the purpose of illustration, let us assume that it is 0.05. In (7), we expand the feature geometry of signs by assuming a REGISTER attribute whose value specifies the type of register (as a value of TYPE) and its probability in this type of register (as a value of WEIGHT).

(7)
$$\begin{bmatrix} \textit{head-filler-phrase} \\ \textsc{non-head-dtrs} & \left\langle \begin{bmatrix} \textsc{synsem}|\textsc{loc}|\textsc{cat}|\textsc{head} & \begin{bmatrix} \textit{verb} \\ \textsc{vform} & \textit{fin} \end{bmatrix} \end{bmatrix} \right\rangle \end{bmatrix} \Rightarrow \begin{bmatrix} \textsc{c-cont}|\textsc{reg} & \begin{bmatrix} \textsc{type} & \textit{1-F} \\ \textsc{weight} & \textit{0.05} \end{bmatrix} \end{bmatrix}$$

A set of constraints corresponding to a different register (e.g. Set 1-I above) would contain a different version of this constraint, thus assigning a different probability, i.e. a different value of WEIGHT, to REGISTER.

Under this approach, each sentence can be analysed relative to a particular register grammar (i.e. a particular probability distribution over register-relevant features). In addition to an analysis of the syntax and semantics of the sentence, the weight/probability of the topmost node can then be interpreted as the register score of that sentence, reflecting the probability (and therefore perhaps also the appropriateness) of that sentence with respect to that register.

An interesting feature of this approach to register-modelling is that, in principle, different subtypes of registers can also be modelled, possibly reflecting different stages in language acquisition. The stage at which we acquire a specific *word* or a *grammatical constraint* and the stage at which we acquire the appropriateness constraints to its *use in specific situations* do not need to overlap. Usage constraints are more dynamic than grammatical constraints – they change easier over time than the latter ones do. Furthermore, usage constraints are closely related to social interactions and the rules imposed by them. Therefore, it is to be expected that in new social interactions new weights or probabilities will arise. For example, at some point in our development we might discover a distinction between the grammatical (informal) constructions we use with our friends and with our parents (e.g. the use of *Digga* 'bro' in contemporary German youth language), cf. Figure 4. Similarly, at a later point in our development, we might distinguish subtypes of formal language in academic situations, in a job interview, etc. The analyses of such properties and the formal constraints derived from them have to be valid in the light of empirical data (corpus or experimental) and constraints from the linguistics–sociology–psychology interface (cf. Lüdeling et al., 2022).

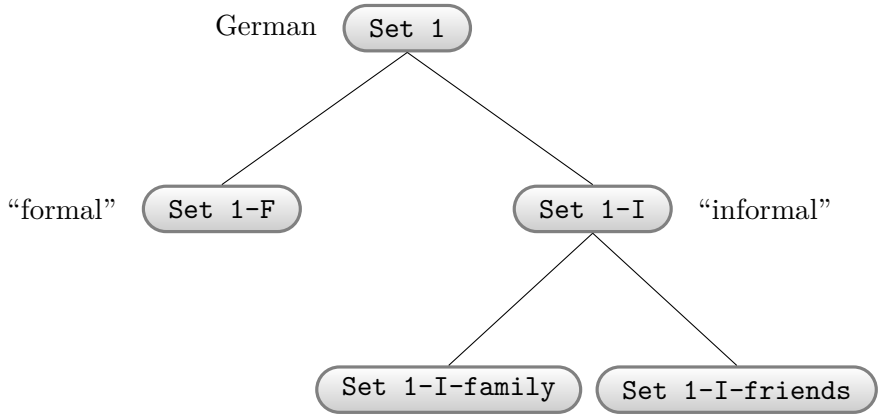

Figure 4: Modelling three registers of German

The downside of this approach is that in order to compare the appropriateness of a sentence across different registers, it is necessary to parse the sentence once for each register, each time using the set of constraints corresponding to the respective register. From a psycholinguistic point of view, it seems rather implausible that humans parse a given sentence using a number of different grammars in parallel. However, under a model that assumes multiple grammars to model variation, we see no way around this. Therefore, we suggest a different approach using one grammar that includes all information about known/acquired registers and that deals with all aspects mentioned in this section.

3 One grammar with information about several registers

The alternative approach assumes that there is a single grammar enriched with information about any sign's probability distribution *across* registers. For this purpose, we introduce a REGISTER feature next to PHON and SYNSEM on the outer level of the sign, cf. (8). In comparison to other register approaches in HPSG (cf. Paolillo, 2000; Bender, 2001, 2007; Asadpour et al., 2022), the values we propose for the REGISTER attribute do not say anything about social meaning, and are therefore not contained within CONTEXT. What our exploratory approach provides are merely the probabilities of a sign in all registers recovered from the corpus (see Schäfer, Bildhauer, Pankratz & Müller 2022). Up to this point, we are agnostic about whether or not a sign has a social meaning, and if so, how it can be characterized (cf. "*not educated*" in Bender, 2007 or "*correct*" in Paolillo, 2000). If present, this information may be stored as part of the CONTEXT attribute, as elaborated recently by Asadpour et al. (2022).

As in the approach sketched in the previous section, we assume that all signs bear information about registers, thus the REGISTER feature is appropriate for lexemes, for inflectional, and derivational lexical rules as well as for syntactic schemata. In contrast to the multiple-grammar approach, however, all signs carry information about all registers, not only about one particular register. Assuming (for instance) that there are seven registers, the architecture of a sign would look as follows:[4]

(8)
$$\begin{bmatrix} \textsc{phon} & \textit{list of phonemes} \\ \textsc{synsem} & \textit{synsem} \\ \textsc{register} & \begin{bmatrix} \textit{reg} & \\ \textsc{register}1 & \textit{value} \\ \textsc{register}2 & \textit{value} \\ \ldots & \\ \textsc{register}7 & \textit{value} \end{bmatrix} \end{bmatrix}$$

Similarly to the approach using multiple grammars, we need a way to determine the weights/probabilities of the mother from the corresponding values of the daughters and of the schema/rule that licenses the combination.[5] In the single-grammar approach (as well as in the multiple-grammars

[4]The number of registers (as pointed out in Section 2) has to be inferred empirically, and an implementation of such an inference procedure is described in Schäfer, Bildhauer, Pankratz & Müller (2022). The number or registers in (8) is arbitrary and was chosen for the purpose of illustration.

[5]In other accounts dealing with register connected to social meaning (e.g. Paolillo, 2000), the register information of the mother is computed by the set union of the register

approach) these computations can be accomplished by a function *reg*. This function collects the values of REGISTER1, …, REGISTER7 of every daughter and of the constraint licensing their combination, and calculates the values of REGISTER1, …, REGISTER7 of the mother.[6] In the full implementation, the function *reg* will be interpreted as a Bayesian update function adjusting the probabilities readers/hearers assign to the set of registers.

In contrast to the approach outlined in the previous section, a full representation of a sentence includes weights/probabilities for each register. Register appropriateness can then be compared across different registers with one parse. For this advantage, the single-grammar approach appears as superior to the multiple-grammars approach not only in terms of computational efficiency, but also regarding cognitive plausibility.

4 Conclusion

In this paper, we have discussed multiple-grammar and single-grammar approaches to language-internal variation such as register in HPSG. We showed that an architecture similar to the CoreGram project can be adapted to the development of subgrammars encoding different registers of one language. Due to the probabilistic nature of register knowledge, probabilities of linguistic signs need to be specified in the subgrammars for each register. An alternative single-grammar approach was also sketched, where the discrete probability distributions over the set of registers are stored with each sign. We argued that the single-grammar approach is preferable, because it allows us to evaluate the register properties of each sentence with a single parse instead of one parse per register. These fundamental considerations are part of the foundations for a planned long-term project wherein fine-grained register distinctions as discovered in our data-driven work (Schäfer, Bildhauer, Pankratz & Müller, 2022) are implemented in a register-aware probabilistic HPSG.

It is worth mentioning that the study of register-driven variation in conjunction with deep morphosyntactic analyses still has unresolved issues, but at the same time it raises promising research questions, such as: (i) How can frequentist or probabilistic approaches be integrated into the grammatical component (a question we partially answer here)? (ii) How can social-

values of the daughters to see whether an utterance satisfies or not the felicity conditions of the register. In that sense, our approach – if combined with social meaning – can be seen as a way to *quantify* to which extent the utterance satisfies the felicity conditions.

[6] Manfred Sailer (p.c. 2022) pointed out to us that it is important that *reg* does not take into account the *order* in which constraints are applied, otherwise leading to register constraints that would be fundamentally different from ordinary constraints in HPSG. As mentioned in Section 2, the mathematics behind our account are not worked out yet, but the importance of the order-independent application of constraints has to be taken into account.

meaning approaches be combined with probabilistic approaches in order to account for register-driven variation (and is this necessary)? (iii) How can the feature-geometry of HPSG be extended to include discourse-level phenomena, since register-driven variation is often influenced by discourse factors?

References

Abney, Steven P. 1997. Stochastic attribute-value grammars. *Computational Linguistics* 23(4). 597–618.

Adger, David. 2006. Combinatorial variability. *Journal of Linguistics* 42(3). 503–530. doi:10.1017/s002222670600418x.

Argamon, Shlomo Engelson. 2019. Register in computational language research. *Register Studies* 1(1). 100–135. doi:10.1075/rs.18015.arg.

Asadpour, Hiwa, Shene Hassan & Manfred Sailer. 2022. Non-wh relatives in English and Kurdish: Constraints on grammar and use. In Stefan Müller & Elodie Winckel (eds.), *Proceedings of the 29th International Conference on Head-Driven Phrase Structure Grammar, Nagoya University & Institute for Japanese Language and Linguistics*, 6–26. Frankfurt/Main: University Library. doi:10.21248/hpsg.2022.1.

Bender, Emily M. 2001. *Syntactic variation and linguistic competence: The case of AAVE copula abscence*: Stanford University PhD thesis. https://faculty.washington.edu/ebender/dissertation/bender_thesis.pdf.

Bender, Emily M. 2007. Socially meaningful syntactic variation in sign-based grammar. *English Language and Linguistics* 11(2). 347–381.

Bender, Emily M., Dan Flickinger & Stephan Oepen. 2002. The Grammar Matrix: An open-source starter-kit for the rapid development of cross-linguistically consistent broad-coverage precision grammars. In John Carroll, Nelleke Oostdijk & Richard Sutcliffe (eds.), *COLING-GEE '02: Proceedings of the 2002 Workshop on Grammar Engineering and Evaluation*, 8–14. Taipei, Taiwan: Association for Computational Linguistics. doi:10.3115/1118783.1118785.

Biber, Douglas. 1988. *Variation across speech and writing*. Cambridge: Cambridge University Press. doi:10.1017/cbo9780511621024.

Biber, Douglas. 1995. *Dimensions of register variation*. Cambridge: Cambridge University Press. doi:10.1017/cbo9780511519871.

Biber, Douglas & Susan Conrad. 2009. *Register, genre, and style*. Cambridge: Cambridge University Press. doi:10.1017/cbo9780511814358.

Blei, David M., Andrew Y. Ng & Michael I. Jordan. 2003. Latent Dirichlet allocation. *Journal of Machine Learning Research* 3. 993–1022. doi:10.1145/1015330.1015439.

Bouma, Gosse & Gertjan van Noord. 1998. Word order constraints on verb clusters in German and Dutch. In Erhard W. Hinrichs, Andreas Kathol &

Tsuneko Nakazawa (eds.), *Complex predicates in nonderivational syntax* (Syntax and Semantics 30), 43–72. San Diego, CA: Academic Press. doi: 10.1163/9780585492223_003.

Brew, Chris. 1995. Stochastic HPSG. In Steven P. Abney & Erhard W. Hinrichs (eds.), *Proceedings of the Seventh Conference of the European Chapter of the Association for Computational Linguistics*, 83–89. Dublin: Association for Computational Linguistics.

Davis, Anthony R., Jean-Pierre Koenig & Stephen Wechsler. 2021. Argument structure and linking. In Stefan Müller, Anne Abeillé, Robert D. Borsley & Jean-Pierre Koenig (eds.), *Head-Driven Phrase Structure Grammar: The handbook* (Empirically Oriented Theoretical Morphology and Syntax 9), 315–367. Berlin: Language Science Press. doi: 10.5281/zenodo.5599834.

Fasold, Ralph W. & Dennis R. Preston. 2007. The psycholinguistic unity of inherent variability: Old Occam whips out his razor. In Robert Bayley & Ceil Lucas (eds.), *Sociolinguistic variation: Theory, methods, and applications*, 45–69. Cambridge: Cambridge University Press. doi: 10.1017/CBO9780511619496.004.

Flickinger, Daniel P. 2000. On building a more efficient grammar by exploiting types. *Natural Language Engineering* 6(1). 15–28.

Flickinger, Daniel P., Ann Copestake & Ivan A. Sag. 2000. HPSG analysis of English. In Wolfgang Wahlster (ed.), *Verbmobil: Foundations of speech-to-speech translation* (Artificial Intelligence none), 254–263. Berlin: Springer-Verlag. doi:10.1007/978-3-662-04230-4.

Guy, Gregory R. 1996. Post-Saussurean linguistics: Toward an integrated theory of language. *University of Pennsylvania Working Papers in Linguistics* 3(1). 1–24.

Guzmán Naranjo, Matías. 2015. Unifying everything: Integrating quantitative effects into formal models of grammar. In Johannes Wahle, Marisa Köllner, Harald Baayen, Gerhard Jäger & Tineke Baayen-Oudshoorn (eds.), *Proceedings of the 6th Conference on Quantitative Investigations in Theoretical Linguistics*, none. Tübingen: Tübingen University. doi: 10.15496/publikation-8636.

Hilpert, Martin. 2013. *Constructional change in English. Developments in allomorphy, word formation, and syntax.* Cambridge: Cambridge University Press. doi:10.1017/CBO9781139004206.

Hinrichs, Erhard W. & Tsuneko Nakazawa. 1994. Linearizing AUXs in German verbal complexes. In John Nerbonne, Klaus Netter & Carl Pollard (eds.), *German in Head-Driven Phrase Structure Grammar* (CSLI Lecture Notes 46), 11–38. Stanford, CA: CSLI Publications.

Hudson, Richard. 1997. Inherent variability and linguistic theory. *Cognitive Linguistics* 8(1). 73–108. doi:10.1515/cogl.1997.8.1.73.

Jackendoff, Ray & Jenny Audring. 2020. *The texture of the lexicon: Relational Morphology and the Parallel Architecture.* Oxford: Oxford Univer-

sity Press. doi:10.1093/oso/9780198827900.001.0001.

Kiss, Tibor. 1995. *Infinite Komplementation: Neue Studien zum deutschen Verbum infinitum* (Linguistische Arbeiten 333). Tübingen: Max Niemeyer Verlag. doi:10.1515/9783110934670.

Labov, William. 1969. Contraction, deletion, and inherent variability of the English copula. *Language* 45(4). 715–762. doi:10.2307/412333.

Lüdeling, Anke, Artemis Alexiadou, Aria Adli, Karin Donhauser, Malte Dreyer, Markus Egg, Anna Helene Feulner, Natalia Gagarina, Wolfgang Hock, Stefanie Jannedy, Frank Kammerzell, Pia Knoeferle, Thomas Krause, Manfred Krifka, Silvia Kutscher, Beate Lütke, Thomas McFadden, Roland Meyer, Christine Mooshammer, Stefan Müller, Katja Maquate, Muriel Norde, Uli Sauerland, Stephanie Solt, Luka Szucsich, Elisabeth Verhoeven, Richard Waltereit, Anne Wolfsgruber & Lars Erik Zeige. 2022. Register: Language users' knowledge of situational-functional variation. *Register Aspects of Language in Situation* 1. 1–58. doi: http://dx.doi.org/10.18452/24901.

Meurers, Walt Detmar. 2000. Lexical generalizations in the syntax of German non-finite constructions. Arbeitspapiere des SFB 340 145 Universität Tübingen Tübingen. http://www.sfs.uni-tuebingen.de/~dm/papers/diss.html.

Miyao, Yusuke & Jun'ichi Tsujii. 2008. Feature forest models for probabilistic HPSG parsing. *Computational Linguistics* 34(1). 35–80. doi: 10.1162/coli.2008.34.1.35.

Müller, Stefan. 2013. *Head-Driven Phrase Structure Grammar: Eine Einführung* (Stauffenburg Einführungen 17). Tübingen: Stauffenburg Verlag 3rd edn.

Müller, Stefan. 2014. Kernigkeit: Anmerkungen zur Kern-Peripherie-Unterscheidung. In Antonio Machicao y Priemer, Andreas Nolda & Athina Sioupi (eds.), *Zwischen Kern und Peripherie: Untersuchungen zu Randbereichen in Sprache und Grammatik* (Studia grammatica 76), 25–39. Berlin: De Gruyter.

Müller, Stefan. 2015. The CoreGram project: Theoretical linguistics, theory development and verification. *Journal of Language Modelling* 3(1). 21–86. doi:10.15398/jlm.v3i1.91.

Newmeyer, Frederick J. 2003. Grammar is grammar and usage is usage. *Language* 79(4). 682–707.

Paolillo, John C. 2000. Formalizing formality: An analysis of register variation in Sinhala. *Journal of Linguistics* 36(2). 215–259.

Pierrehumbert, Janet B. 2008. Word-specific phonetics. In Carlos Gussenhoven & Natasha Warner (eds.), *Laboratory phonology 7*, vol. 4–1 Phonology and Phonetics, 101–139. de Gruyter. doi:10.1515/9783110197105.1.101.

Schäfer, Roland, Felix Bildhauer, Elizabeth Pankratz & Stefan Müller. 2022. Modelling registers. Ms. Humboldt-Universität zu Berlin.

Søgaard, Anders & Petter Haugereid. 2007. A tractable typed feature structure grammar for Mainland Scandinavian. *Nordic Journal of Linguistics* 30(1). 87–128. doi:10.1017/S0332586507001667.

Solt, Stephanie. 2015. Vagueness and imprecision: Empirical foundations. *Annual Review of Linguistics* 1(1). 107–127. doi:10.1146/annurev-linguist-030514-125150.

Yang, Charles. 2002. *Knowledge and learning in natural language*. Oxford University Press. doi:10.1007/978-1-4419-1428-6_837.