

## Generating preview word maps in the DMW project

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### 1 Introduction

The DMW project –funded by the Academy of Sciences and Arts of Northrhine-Westfalia, Germany, and involving the universities of Bonn, Münster, Paderborn and Siegen– is a long-term project (2016-3032) that aims at digitally collecting, analyzing, storing, presenting and preserving dialect data in the western part of Germany (mainly Northrhine-Westfalia).<sup>1</sup> To make this possible, we digitally record spoken data in ca. 800 different places, with four informants per place, each two of them aged ‘30-45’ and ‘70+’, respectively. We use a questionnaire of more than 600 succinct tasks, according to which the informants mostly have to answer open and yes/no-questions, to describe pictures or video scenes with a term, or to read sentences in their non-standard manner of speaking. These data are processed (cutting/segmentation and analysis of the sound files), and presented on dynamically generated maps (so-called *preview maps*) of a digital dialect atlas of the region.

We distinguish between two versions of the digital, dynamic DMW atlas according to the user types addressed: first, a standard, public version (aka “Speaking DMW”) described in this paper, which allows to directly view the distribution of dialectal/non-standard utterance variants in space, and to listen to the corresponding recordings (these are either the answers to some question on a “word map”, or the Wenker sentences read out by the informants on “Wenker sentence maps”); second, an extended expert version with restricted Shibboleth access, which will also portray the distribution of ca. 1200 dialect phenomena variants (gathered for comparison with other dialect atlases). Both versions are based on visually presenting the variants in categorized form (“taxates” in Goebel 2010’s terminology), yet the types/taxates are determined *automatically* in the former according to the scheme described below, *intellectually/manually* in the latter. In the final phase of the project, some of the phenomena-related data will be evaluated and published as classic, annotated dialect maps of the region.

*Preview maps*<sup>2</sup> systematically depart from classic dialect maps in at least the following respects. Preview maps are inherently digital and dynamic, i.e., they are instantaneous projections of actual analyzed data generated automatically on-line as a result of a user query. By offering various kinds of selection and presentation options, they are interactive and can be used for visual exploration of *all available* dialect data even by lay people from early on. Yet they lack classic, evaluation-based dialectal annotations ((core) dialect areas, isoglosses etc.) or fully theory-driven data clusters and variant types.

In contrast to that, *classic dialect maps* are static (print-oriented), non-interactive, non-explorative maps constructed manually by experts for experts. They are based on time-consuming *evaluation* of –mostly

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<sup>1</sup> See Spiekermann et al. (2016ff) for general information about the project; for an overview of the workflow, see Carstensen et al. (2020).

<sup>2</sup> Preview maps as presented here have been introduced in the [SiSAL project](#) (Solau-Riebel/Vogel 2013-2016), albeit in a much smaller scale, and with much more manual data preparation.

selected– data and portray them as filtered by intellectual considerations and with corresponding dialectological annotations. Apart from different possibilities and habits of information presentation in modern times (non-print, user-friendly, computer-generated, interactive, explorative, conforming to GUI principles), an important disadvantage is the expectable time lag for classic dialect maps, because they require complete data sets for the selected phenomena. This makes preview maps the primary (and for the most part, only) option for the DMW, given the size of the project (number of informants, questions, phenomena) and the maxim to use digital technology throughout.

Irrespective of the classic/non-classic contrast regarding intellectual evaluation, current preview maps are different from most, if not all, computational approaches to dialectology in dialectometrics or geolinguistics (see, Lameli et al. 2010 for an overview) in that they do *not* show statistical analyses of more than one item or feature (“global” analyses in Goebel’s terms). Instead, they are intended to easily identify aspects of variant distribution in space for particular analyses/items, given massive data variation. The present paper describes generating *preview word maps* based on the transcriptions of uttered words like the one shown in Figure 1, to be distinguished from *preview phenomenon maps* showing the variants derived from theory-based analyses (of some phonetic, morphological, lexical, or syntactic aspect of uttered words) that will be developed later.

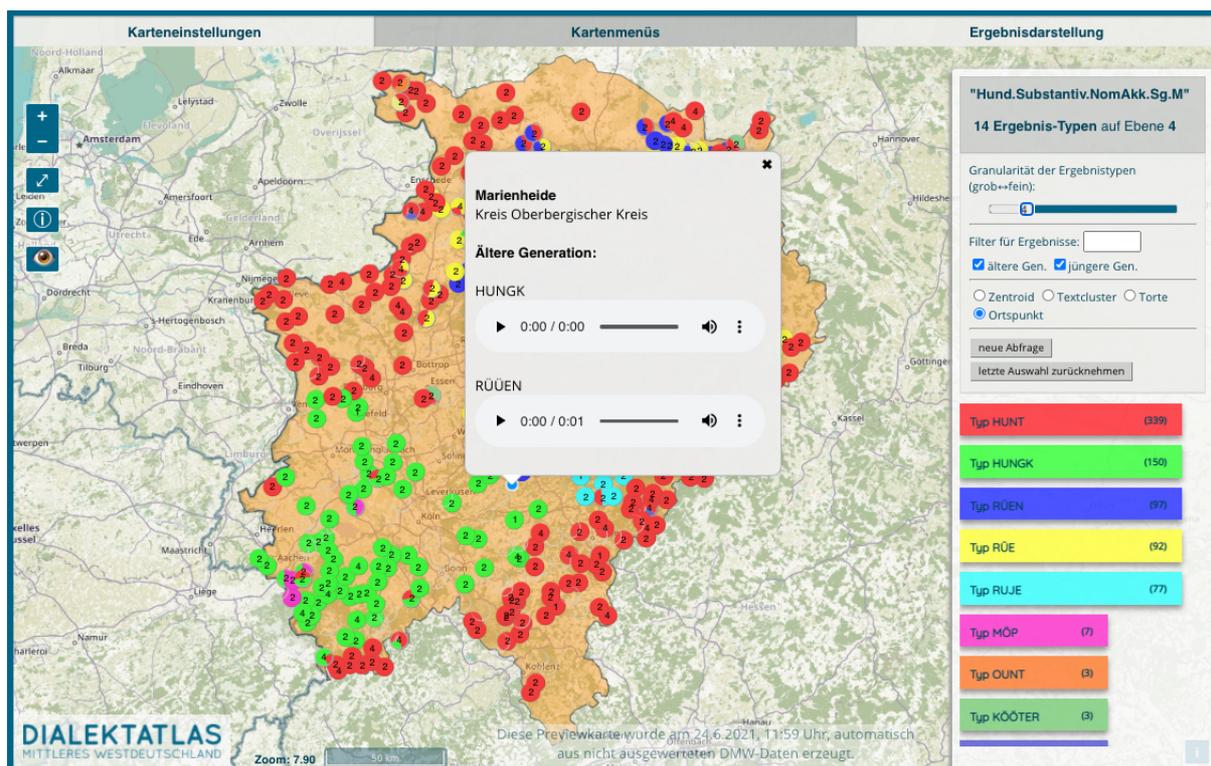


Figure 1: Preview map of Hund

At the beginning, we faced a number of challenges to be met for a success of the DMW project: efficient, error-less, off-line digital fieldwork/interviews/recordings (“exploration”); efficient, error-avoiding, computer-assisted high-quality transcription; effective automatic visualization of dialect data using up-to-date web technology. To exemplify this with current numbers: as of June, 1<sup>st</sup>, 2022, we have cut and transcribed ~590.000 spoken words of more than 550 explored places, and in the presentation of a

word map, the number of variants of a single word can easily reach 100, or even 200 (of already generalized IPA transcripts). Figure 1 shows how our preview maps can give a rough indication of data distribution in spite of massive data variation (in this case, more than 60 already generalized variant types for the word *Hund*, reduced to a display of 14 types) by choosing certain clustering and visualization options.

In following, I will first describe the data and workflow in the DMW project, with a focus on the computer-assisted transcription (aspects of the computer-assisted exploration are further discussed in Gehrke et al. 2020), introducing our literal “popular” transcription (POP). After that, I will give a detailed account of our POP-based algorithm for handling massive dialect data to achieve effective visualization. Finally, I will elaborate on the technical aspects of preview word map generation in the DMW project for the standard version, also showing the possibilities of its interactive and explorative use.

## 2 Work and data flow in the DMW project

Basically, technical aspects in the DMW project can be described as entering, retrieving and modifying data of our central database (apart from storage of audio data in the scientific cloud Sciebo). From early on, handling DMW data was conceived as human-computer interaction via (graphical user) interfaces: the *acquisition interface* for handling contact (action) information for places to be explored; the *exploration interface* for uploading personal information and (meta-)data of the interviews; the *analysis interface* as a work area to handle informant data (cutting sound files, transcribing utterances, and handling phenomena aspects); the *map (presentation) interface* presenting preview maps for selected queries of some user. Figure 2 gives an overview of the simplified work and data flow structure of the DMW project.

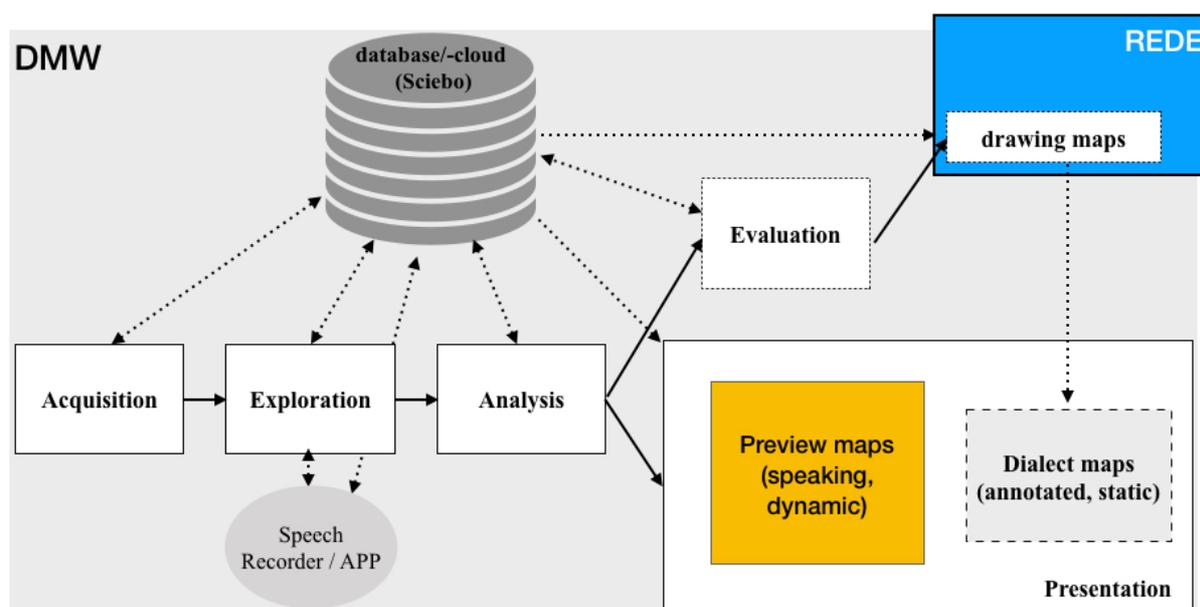


Figure 2: Global view of work and data flow in the DMW project

Note that production/drawing of classic, static dialect maps is planned but not yet done, hence the different graphical appearance as dashed components. It requires both a stage of intellectual evaluation

of the analyzed data, and manual production of maps (which will be done with the map drawing tools provided by REDE, see Schmidt et al. 2008ff).

Over the years, additional functionalities and tools requiring database interactions were developed. One of them is the *IPA repair tool* that allows to easily spot transcription errors by listing selected data, and to quickly correct them via the offered shortcuts to the corresponding (parts of) the analysis interface (see below for more information). While the interfaces were originally viewed as wholistic web applications covering the central aspects of our work flow, we therefore rather built a structured internal web presentation for our project (with corresponding work flow areas) in which the interfaces, but also other web-based functionalities, were placed accordingly.

## 2.1 Acquisition

In general, we require exploration places to be a subset of the classic Wenker places constrained by a certain range of inhabitants (500 to 8000) and some scheme of distribution: we use a raster overlay of our exploration area to arrive at an equally distributed selection of places to be explored, each partner university being responsible for a certain part. The acquisition interface involves a WebGIS application showing area, raster and Wenkerorte, as well as filterable layered information about the places (aspects of the contact status and (partial) exploration status of age groups to be explored). A click on a place accesses the acquisition interface proper which allows to enter and view contact data as well as time stamped acquisition actions (contacting persons via phone or mail, placing advertisements, distribution of informant questionnaires etc.). Once established, this interface provided a remarkable facilitation of acquisition planning and coordination.

## 2.2 Exploration

For the digital explorations, we use the SpeechRecorder® app (Draxler/Jänsch 2004, 2019) with which the answers of the informants to the questions of the exploration questionnaire are automatically cut and systematically stored – an enormous saving of time, and hence, man power, for the subsequent analysis stage. Unfortunately, the SpeechRecorder was designed for use as a laboratory software, which does not guarantee uniqueness of identifiers or easy adjustments of the built-in questionnaire when used distributedly in different locations, on various computers, and in the field. We needed to come up with a quick solution for these problems since explorations were supposed to start immediately.

We opted for dedicated semi-automatic work flows using python scripts to handle the necessary organizational data structures. The first python script transforms the original exploration questionnaire into the XML format required by the SpeechRecorder. It is applied semi-automatically every time the questionnaire is modified (which happened quite often in the beginning of the project). Then, before an exploration, each explorer of university with id U requests a “SpeechRecorder project” for an informant with –a unique– identifier ID. This automatically fires the second python script, creating unique project files (using U and ID) and bundling them into a downloadable zipped SpeechRecorder project importable by the SpeechRecorder. U and ID, together with the question numbers of the “SpeechRecorder Script”, are used to name the corresponding audio files of the answers. After the

exploration, the folder containing audio files is uploaded into the cloud, accessible for use in the analysis and map interfaces.

The exploration interface is used by the explorer to store information noted in the *exploration protocol* (remarks about the setting –ambience, technicalities, other persons present, characteristics of the informant– and about aspects of specific answers). Even before the exploration, it is also used to enter all information about the informant (a prerequisite for the exploration).

## 2.3 Analysis

Analysis in the DMW project roughly divides into treating sound aspects of an answer, transcribing the relevant answer word(s), and handling phenomena information. The analysis interface (see Figure 3) allows to make certain selections, e.g., of place, informant, task, analysis part to deal with (in the blue area) or to view relevant (meta) information, for example, about informant, exploration setting, or task/analysis like question asked, and words to be analyzed (in the green area).<sup>3</sup> While wav-handling and transcription (see below) are indispensable for the generation of preview maps, phenomena handling will be performed in later stages of the project. For aspects of metalinguistic information (handling) see Gehrke et al. (2020).



Figure 3: Analysis interface

Sound-related analysis (in section “wav-Bearbeitung” of Figure 3) involves cutting audio files for audio presentations on preview maps (for users to be able to hear the non-standard pronunciation of a word, uttered as part of an answer to some question of the questionnaire). We specify the range of words to

<sup>3</sup> Task handling is restricted, however. To prevent certain analysis artifacts (“analyzer isoglosses”), each analyzing person is exclusively assigned a number of tasks by the coordinator.

cut as so-called RWS (**R**elevant **W**ord(s) for cutting (= **S**chneiden)) and also present the information about the words to be analyzed as so-called RWL (**R**elevant **W**ord(s) for **L**inguistic analysis). For example, we might elicit a prepositional phrase *in the barn* with a question *Where does the farmer store the hay?*. Although we could be interested in various phenomena on distinct linguistic levels addressing different RWLs (say, lexical and phonetic aspects of RWLs *in* and *barn*, syntactic aspects of *in the* or *the barn*), and might want to present some of them audibly, we decided to just cut *one* audio file (containing the span of words with variants of all RWLs, in this case, *in the barn*) for each (sub)task as RWS, for economy reasons. Apart from that, the RWS of a single-noun RWL may be specified as having to include the determiner of the noun, if uttered (see Figure 3). Sound-related analysis then means to perform some action (cutting the RWS, optionally improving sound quality), and to store relevant information (e.g., about the quality/status of the audio file or the answer). Note that an answer might be difficult to hear or identify (in case of multiple speakers or multiple different answers), or be lacking for different reasons (no or wrong answer given, question not asked due to unfinished interview, or question not in questionnaire at interview time).

The transcription part of the analysis interface cycles through the RWLs of the current task/question presenting the corresponding observed variants (“observants”) for phonetic analysis in each case. Transcription is different from simply entering IPA characters (say, via the keyboard) given the audio file, and is rather realized as a computer-assisted process involving a dedicated set of functionalities, with *IPA transcription tool* (ITT) referring to the area of the analysis interface in which this happens (see Figure 4).

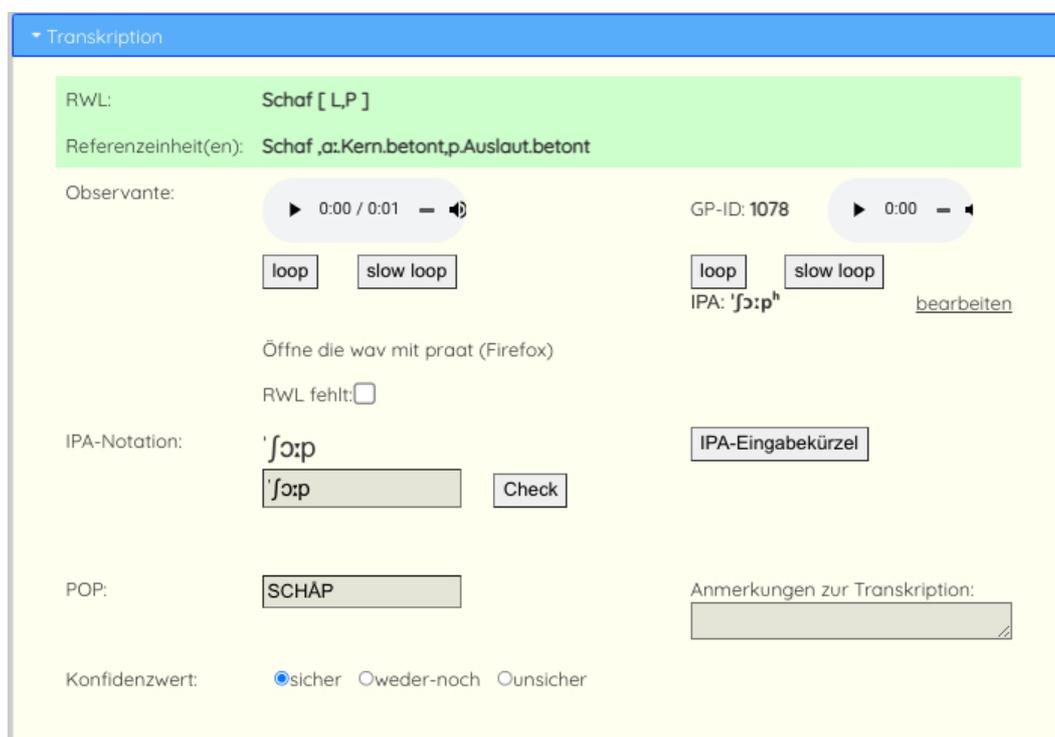


Figure 4: The IPA transcription tool (ITT) as part of the analysis interface

The ITT allows to loop both through the current observant (even in reduced speed) and the observant of the other informant of that place (both helps to identify the specifics of the pronunciation).

Phenomenon-related information is displayed for the analyzing person to know what to listen to in particular. Transcription is always *computed* given the input into the corresponding field (i.e., transcription is semi-automatic), as detailed below. We use a literal “popular” transcription (so-called POP) as a readable version of an observant to be displayed on preview maps (see below). These POPs are computed *automatically* from the computed IPA of the input.

The phenomena handling part of the analysis interface will be used to deal with the ~1200 phenomena to be investigated in the DMW project. Phenomena typically address *parts* of RWLs that have to be identified given the RWL transcript (or the RWS, mostly in the case of syntactic or morphological phenomena of non-transcribed observants). After analysis, the variants of some phenomenon’s reference entity will be displayable on corresponding maps in the map interface. This part is still under construction, however.

## 2.4 Presentation

The results of the analysis of RWLs, as well as the RWSes, are presented on dynamic, unevaluated preview maps as “Speaking DMW” (also collectively called “Atlaskarten”/“Atlas maps”).<sup>4</sup> We distinguish two versions of the map interface. First, the standard version for the presentation of word maps (visually displaying the variants of words), and of the Wenker sentences (both with a “click-and-hear” facility). Second, the “expert” version (only accessible via restricted, university Shibboleth access) showing variants of phenomenon-related RWL parts.<sup>5</sup> By definition, the preview maps involve no further evaluation, and can therefore be generated as soon as there are analyzed data. Correspondingly, the preview maps directly reflect the progress of the project. Only for the later stages of the project, we plan to evaluate (selected) data in order to present classic static annotated dialect maps for the explored region. Such maps will be constructed with the facilities provided by REDE (Schmidt et al. 2008ff).

## 3 Transcription in the DMW

### 3.1 Phonetic transcription in the ITT

Input to the ITT can be either letters, that is, characters of the set [aeioubdghjklmnpqrstvwxyz] (basic IPA symbols). Any other IPA (diacritic) symbol is specified differently, often in more than one way. In general, we only consider a selected set of IPA symbols (but note that we also code syllable boundaries, ambi-syllabic consonants, primary/secondary stress, and syllabic consonants).<sup>6</sup> To code them, certain textual entries can be made to specify IPA symbols (“sch” → [ʃ], “tsch” → [tʃ], “t-sch” → [tʃ̥]), double characters either specify long phones (“aa” → [a:]) or ambi-syllabic consonants (“tt” → [t̪]), and certain added characters specify slight variants (“e#” → [ə], “r#” → [ɹ]). As an alternative, SAMPA (see Wells 1997) character( sequence)s can be used (“S” → [ʃ], “E” → [ɛ], “6” → [ɐ]), also in textual combinations (“t-S” → [tʃ̥]). In the ITT, there is a help button listing all available textual, SAMPA, or combined character sequences coding IPA symbols.

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<sup>4</sup> This is the external terminology for what is project-internally called “map interface”.

<sup>5</sup> In addition to that, simple dialectometrical reference point maps (see Goebel 2010) can be generated.

<sup>6</sup> (Non-)syllabicity is coded redundantly and automatically, as are affrication arcs.



Finally, the analyzing person has to specify her confidence with a three-valued option (secure, insecure, in-between). Only then can the transcription be stored.

Outside the ITT, quality can be checked with the preview maps: if there is an outlier in some homogeneous distribution of variants, this is at least a hint to examine the corresponding transcription of the outlier. Likewise, the variants on the preview maps can be filtered by confidence value to identify non-secure transcripts. For both cases, there is an *IPA Repair tool* that offers the possibility to quickly enter an RWL and (at least either) a part of the IPA or POP, or of the place name. As an example, Figure 6 shows the query “list data for ‘Trog’, where IPA contains ‘d’ and POP contains ‘A’” and part of the table of corresponding results. For easy inspection, the result section is sortable by a click on one of the column titles, and can be filtered by using the full-text search field. The observants can easily be listened to, and links to the corresponding instantiations of the ITT – and also the whole analysis interface– for immediate modification (“Bearbeiten”)/correction are provided.

GP-ID	TA-ID	POP	RWL	IPA	Wav-status	Audio	Link	Ort	Datum
7	04_020_2	DRAUCH	Trog	'dʀaʊx	Qualität OK;;;		<a href="#">Bearbeiten</a> <a href="#">AI Link</a>	Erp	2020-03-02
472	04_020_2	DRUACH	Trog	'druʌx	Qualität OK;;;		<a href="#">Bearbeiten</a> <a href="#">AI Link</a>	Fretter	2020-06-11
517	04_020_2	DRACH	Trog	'drax	Qualität OK;;;		<a href="#">Bearbeiten</a> <a href="#">AI Link</a>	Hümmerich	2019-11-07

Figure 6: The IPA Repair tool of the DMW project

### 3.2 Literal transcription: POPs

Especially due to the many non-expert users of the DMW system, a transliteration of the IPA transcripts of utterances to their readable textual representation is mandatory at least for the word maps. We decided to use the *Hamburgian transcription conventions* (“Hamburger Transkriptionskonventionen”, HTC, see Bieberstedt et al. 2016) for this purpose, whose maxim is to “[achieve] an exact reproduction

etc.). Above all, there is an IPA transcription *training tool* that mimics the ITT and allows to perform transcription with selected tasks and test data.

of pronunciation as much as possible, while providing good readability, ensured by using the standard alphabet and a minimum number of special characters (only å)” (Bieberstedt et al. 2016:421, my translation). We call the resulting literal transcripts *POPs* (from “popular”), and write them in uppercase letters.

It is a characteristic of literal transcription that diacritics and prosodic markers are left out, and that certain non-ASCII symbol( sequence)s are systematically mapped on certain character( sequence)s. Examples of the HTC are [ɛ] → <E>, [ɔ] → <O>, [ɔ:] → <Å>, [ɔ::] → <ÅÅ>, [ɔ̃] → <EU>, [ʃ] → <SCH>, [d͡ʒ] → <DJ>, [ŋ] → <NG>. Other rules determine how to transcribe syllabic consonants K (as <K'>) or how to mark relevant syllable boundaries (with <->). A large part of the HTC is concerned with the textual marking of vowel length (e.g., when to mark shortness with a double consonant: [kɪnɐ] → <KINNER>, [lɔft] → <LUFT>/\*<LUFFT>, [ʃvɪmt] → \*<SCHWIMT>/<SCHWIMMT>). On the whole, the HTC provide a good standard for the task of literal transcription, and have been implemented in our system (although automatic realization is less than perfect). It must be noted that the HTC, as our POP conventions, have three main disadvantages, however.

First, they were designed especially for the Hamburgian Low German, while half of Northrhine-Westfalia covers Middle German areas showing regional phonetic phenomena not covered by the conventions, for example, the so-called “Tonakzent” (phonemically relevant intonation), the voiced velar fricative ([ɣ]), voiced labio-velar approximants ([w]), or different variants of /r/.

Second, their intended use was for directly/manually transcribing spoken dialect, the focus being on the identification of the words uttered. Because of that, they include rules that guarantee recognition of the lexeme, not only of the phonation: for example, while [ts] could be transcribed as <TS>, it has to be transcribed as <Z> at the beginning (as in [tsa:n] → *Zahn* (tooth)), and as <TZ> at the end of the word/syllable ([kats̃] → <KATZ>). This standard-language oriented transcription is most obvious in the double-consonant rule following the “morphological principle” in orthography: a consonant is written twice because the lexeme shows this duplication (for example, [brɛnt] is transcribed as <BRENNT>, not as <BRENT>, because the verb is *brennen* (burn)).<sup>8</sup> Similarly, the final unstressed central vowel [ɐ] is to be transcribed as <ER> (but as <A> after [ɛ] or [ee]). Since standard words are the starting points of word maps (“Holz”, “Zahn”, “Feuer”), all this would not have been necessary in the DMW. On the other hand, and thereby different from standard language, the conventions expect an additional hyphen in the case of syllable gaps as in *inadequate*: <IN-ÄDIKWET>. Unlike handling [ts], final [k] is not to be transcribed as <CK> (as in *dick* and *Stock*), but as <KK>. Furthermore, while [ɛ] is mapped to <E> by default, [ɛi] is to be transcribed as <ÄI> (so-called “Hamburgian

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<sup>8</sup> The adaptation according to the morphological principle is (and can be) done only for the current RWL (and its standard form). Therefore, the variant DACHJESCHOS of *Dachboden* only has one final “s”, although JESCHOS corresponds to *Geschoss* with “ss”. The missing implicit human-in-the-loop, needed for aspects like these, could be regarded as another disadvantage of the HTC for our automatic literal transcription. Note, however, that the authors of the HTC are open to adaptations and modifications of the conventions in principle (Jürgen Ruge, pers. comm., see also Ruge 2019).

diphthongization”). This mixture of rules, adaptations to standard writing, and exceptions, complicate the automatic/ digital use of the conventions, which raises the possibility of errors and might slow down performance.<sup>9</sup>

The third disadvantage concerns the use of <E> and <O> for [ɛ] and [ɔ], respectively. Again, while this may be sufficient for literal transcription (and is also motivated by easy recognition of the words in their standard writing), it might be regarded as unsatisfactory in a dialect atlas due to the elimination of interesting variation.<sup>10</sup> For this reason, the map interface offers an option to select “narrow” literal transcription (“lautnahe Transkription”) in which [ɛ] is mapped to <Ä> (not to <E>), [ɜ]/[œ] to <Œ> (not to <Ö>), and [ɔ] to <Å> (which codes [ɔ:] by default; therefore, not to <O>). Further candidates for narrow transcription could be [ʒ] (to be transcribed as <J> according to the HTC, and hence confusable with the transcription of [j]), [ɣ] (not as <CH>), or characteristic variants of /r/.

#### 4 Handling massive variation in the DMW data for the presentation of preview maps: the DMW POP algorithm (DPA)

##### 4.1 The problem

For typical words, dozens of variants (IPA types) can easily be observed (e.g., for the item *Kette*) in our data, especially as our region comprises both Low German and High German parts. The situation gets worse if there are lexical variants of a word (for *Mädchen* ('girl'): added variants of *Deern*, *Wicht* and *Lüüt*), in which case the number of IPA types can go into the hundreds. Although literal transcription abstracts from specific pronunciation aspects, the number of POPs for an item/RWL still often is very high.

This presents several problems for a system that aims at generating user-friendly visualizations. Above all, there is the sheer *size* of data variance: Even with a smaller set of POP types, the number of signifiers is still too large for effective visualization of the data. Without further intellectual categorization of the signifiers, it is therefore necessary to add an automatic clustering step to prevent cluttering the preview maps with symbols. Then there is the problem of *symbolization* of signifying, say, more than 3-5 variant types. Existing dialect data visualization systems use specific symbols, colour, or a mixture of both for that purpose. Especially when using symbols, they run into the problem of visual confusion, however, especially if the symbols are similar in some respect (e.g. circles containing lines representing different hachures).

The prime challenge therefore was to find a scheme of automatic categorization (a “variant/POP type mechanism”) that replaces intellectual classification as effectively as possible. This excludes simple Levenshtein-based mechanisms as they are linguistically neither motivated nor constrained.

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<sup>9</sup> In some cases, the HTC are inconsistent (in its goals) or incomplete: non-initial [ts] would lead to <WIRTZHAUS>, <MIITZHAUS>, <HOLTZ> for corresponding variants of *Wirtshaus*, *Mietshaus*, and *Holz*.

<sup>10</sup> Especially because phonation is indicated via POPs in preview maps, and because the IPA transcripts are not shown in the standard (lay )version of the map interface.

Development time considerations forbade diving into the field of possible improvements of such methods (see Wieling et al. 2011). Run time considerations ruled out too complex computations, and user interaction requirements called for a non-continuous, qualitative and easily understandable (usually hierarchical) category structure. In general, this excludes quantitative clustering methods that map variation to a graded structure in which categories may not be identifiable (“named”), and which has to be actively manipulated by the user for him/her to gradually select the level of detail for a presentation (as described in Haimlerl 2005:544). Our *DMW-POP-algorithm (DPA)* is therefore different and uses a qualitative, multi-layered Soundex-inspired algorithm, which is described in the following.

## 4.2 Soundex

The Soundex algorithm (see, for example, Wilz 2005) was invented to allow for *phonetic search*, i.e., a phonetically motivated procedure that finds matches for a database lookup (especially of names) despite nonidentical search terms (for cases like Möller/Moeller, Schmidt/Schmitt/Schmied). In general, it operates by mapping phonetically similar names onto common index terms so that lookup reduces to matching index terms, at least for a first selection of probable candidates. More specifically, (one variant of) the algorithm consists of the following steps (simplified):

1. Retain the first letter of the word; map vowel-like letters to zero (A,E,I,O,U,Y,H,W → 0);
2. Map consonant( sequence)s on certain digits (B,F,P,V → 1; C,G,J,K,Q,S,X,Z → 2; D,T → 3; l → 4; M,N → 5; R → 6);
3. Reduce adjacent same digits to one digit (this also holds for the digit of the first letter), then delete zeros;
4. Truncate after three digits; for a shorter word, add zeros until the index term has four characters.

Accordingly, “Wikipedia” is mapped to “W213” (as is, for example, “Wakepod”). There are a number of variants of the Soundex algorithm (e.g., *Metaphone* for English, and “Kölner Verfahren/Phonetik” for German, see Wilz 2005), which mostly use a more sophisticated scheme of the mapping and/or allow for more than three digits (even one for the first letter) to code the index term. Note that one can distinguish between “technical” aspects (e.g., the structure of the resulting index term) and “content” aspects (different kinds of phonetic rules used) of the schemes.

## 4.3 DPA: technical aspects

The DPA departs in several respects from the basic Soundex scheme. First, it starts with approximate phonetic representations ((partial) transliterations of IPA) and, according to this, does not map *words* to approximate phonetic representations of words. Correspondingly, there is no need for sophisticated algorithms accounting for the different textual realizations of phones. Instead, the DPA maps approximate phonetic representations to *generalized* approximate phonetic representations. In particular, this means that the input to the indexing scheme, on the one hand, is an *extended* POP: it may still contain some IPA symbols ([ʒŋœɣx ɣ ]) to ease processing (e.g., handling fricative symbols

instead of <(s)ch>), and for narrow transcription. On the other hand, it is a *partial* POP because the conventions have not yet been fully applied.

Second, unlike Soundex, the DPA does not use a fixed, one-level set of principles for indexing. Instead, it applies the indexing on six levels at the same time, each with a different set of principles resulting in coding different *levels of generalization* of a POP, the levels being ordered from least general (i.e., only containing POPs) to most general. In the Javascript implementation, this results in an array *Types*, with *Types[0]* being the (final) POP, and *Types[5]* being the most general index term. When applied to a set of POPs, the POPs therefore are automatically clustered on corresponding *levels of granularity* of the set, from least granular (most general) to most granular (the level of POPs). All clusters on a level are sorted according to the number of the categorized POPs.

The third departure from the Soundex scheme is the use of a secondary sub-element mapping (on levels  $1 < i < 5$ ). If in an index term set one term is mapped to XXX, and another to YYYYXX or XXXYYYY (on the same level), the second is remapped to XXX. This allows to capture the fact that certain words are sometimes uttered as parts of compounds, and that it makes sense to group them (for example, HEAFSLOOF and LOOF, and HEAPSLAUP and LAUP, respectively) on low-granular levels. Technically, this requires some checks to at least guarantee a high correctness probability of such automatically determined subpart relationship. For example, too short parts (for a level) have to be excluded, as well as accidental parts, so that, on level 4 for *Laub* ('leaves'), the index terms of LOOF-AFFAL, HEASLOOF, LOOFHOOF, HEAFSLOOF, HERFSLOOF, LOOFTEPPISCH are mapped correctly to the index term of LOOF. Overall, this mapping scheme reduces cluster numbers per level significantly, without pruning the index terms arbitrarily.

Internally, this multi-layered indexing scheme requires considerable computation effort (sorting, remapping, counting, establishing information structures, relating clusters to their sets of POPs on five levels). This is why computation is restricted (at the moment, to less than 150 types), and the user is asked to set a filter to arrive at a smaller set of types (this might be changed, however).<sup>11</sup>

It is important to note that this granularity mechanism with its automatic determination of clusters, types, and symbolizations is the central, technical characteristic of the DPA, allowing for user-friendly, explorative, selective viewing of variants as the non-manual solution of the above cluttering problem.<sup>12</sup> In the map interface, variants will be presented according to the granularity level chosen, and can even be restricted to a cluster on that level.

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<sup>11</sup> Filtering is possible via selecting a cluster on some level (thereby restricting the set of variants to those of that cluster), or by textually filtering the POPs via some regular expression to restrict the current variant set.

<sup>12</sup> While the content aspects are no less important, they represent a tentative proposal, and are open to debate and modification.

#### 4.4 DPA: content aspects

The content aspects of the DPA consist of applying some version of the indexing scheme on each level of granularity. They can be arbitrarily chosen, and are only constrained by the rule that with every level of granularity above POP level, the principles must become more general. In the current implementation, the following steps of increasing generality are used:

1. Abstract from specific vowels, build vowel categories, here: frontal (“vorne”), medial (“zentral”), back (“hinten”) vowels by “v/z/h”, correspondingly; mark identity (textual length marking) of following vowel in a vowel character sequence by “=” (else mark following vowel by “\_”);
2. Abstract from gap marking and vowel length (leave out “-“ and “=”) and condense consonants CC to C.
3. Abstract from vowel quality/category by simply noting “\_”; generalize plosive minimal pairs (P/B by “P”, T/D by “T”, G/K by “K”), and velar/uvular fricatives by “Ç”.
4. Abstract from vowel change (leave a single “\_” for vowel( sequence)s)
5. Only mark first POP character.<sup>13</sup>

Table 1 lists the different types of codes collected and generated for the word *Ei*.

IPA types	'ɔɪ, 'ʔaɪ, 'ʔaɪ, 'ʔa: jə, 'ʔeɪ, 'ʔeɪx, 'ʔæjə, 'ʔeç, 'ʔiç, 'ʔe: jə, 'ʔe: ʏə, 'ʔɔɪç, 'ʔæɪ, 'ʔɔ: ə, 'ʔɔʏe, 'ʔaɪ, 'ʔeʏe, 'aɪ, 'ʔɔɪ, 'ʔa: jə, 'ʔaɪjə, 'ʔeh, 'ʔa:ɪ, 'ʔɔɪ, 'ʔek, 'ʔaɪç, 'ʔe: ə, 'ʔa: ə, 'ʔɔɪ, 'ʔeçk, 'ʔe: jə, 'ʔeçe, 'ʔiʏə, 'ʔɔɪç, 'ʔeɪ, 'ʔeçe, 'ʔuç, 'ʔej
Level 0 (POPs)	AI, EI, ECH, AAI, EU, ÄI, AAJE, ICH, ÄÄJE, ÅI, EUCH, ECHER, EK, EH, OI, AICH, EGGER, EICH, ÄJJE, ÄÄCHE, ÅE, OCHE, AIJE, EEE, AAE, ECHK, ICHE, OICH, UCH, EJ
Level 1	z_, zÇ, z=_ , v_, z=Jz, vÇ, h_, v=Jz, z_Ç, zXXzR, zK, zH, zGGzR, z_X, vJJz, v=YZ, hXXz, z_Jz, z= =, zÇK, vXXz, h_Ç, hÇ, zJ
Level 2	z_, zÇ, v_, zJz, vÇ, h_, vJz, z_Ç, zXzR, zK, zH, zGzR, z_X, vYz, hXz, z_Jz, z, zÇK, vXz, h_Ç, hÇ, zJ
Level 3	_ , _Ç, _J, _Ç, _Ç_R, _Ç, _K, _H, _K_R, _J, _ , _ÇK, _J
Level 4	_ , _Ç, _J, _Ç_R, _Ç, _K, _H, _K_R, _ÇK, _J
Level 5	A, E, Ä, I, Å, O, U

Table 1: Different types of codes for RWL *Ei*

For comparison, Table 2 presents the data for the longer word *Dachboden* (‘attic’).

IPA types	'baʔ.kʰən, 'bɔlə.kən, 'ʃpiʃe, 'ʃpaɪ.ʃe, 'ʃpe: ʧə, 'bal.gə, 'bal.kɪ, 'bal.kɪ, 'baʔ.kən, 'bal.kən, 'bʏçən, 'ʃpiʃe, 'zaʏ.lə, 'zuʌ, bu: 'ɑ: dn, 'ʃpi: ʧə, 'bal.kə, 'ʃpi: ke, 'dak.rɔʏm, 'dax.ʃɔɔtʰ, 'baʔ.kən, 'bal.kʰən, 'bo: dn, 'bɔrə, 'svl.nə, 'baʔ.kɪ, 'dax.bo: dn, 'bal.kʰə, 'ʔuʌn, 'ʔuɲən, 'ʔuʌm, 'ʔuʌn, 'ʃpaɪ. ʧe, 'ʔɔgəlɪn, 'ʃpæə.ʃe, 'zœʌe, 'bo: də, 'ʔɔləm, 'bø: n, 'ʃpaɪ.ʒe, 'ʃpaɪ.ʃe, 'da: k, byɔ. dn, 'bəl.kən, 'zœʌe.ɪs, 'ʔɔʌn, 'dax, bo: dn, 'dax, bɔrən, 'bɔrə, 'hul.dən, 'ʔul.dən, 'lø: f, 'spi: ʧe, 'ʃpaɪ.ʒe, 'sœl.də, 'bʏnə, 'bal.gɪ, 'bœdn, 'by: əl, 'spi: ʃe, 'ʃpi: ʃl, 'ʃpi: ʃe, 'ʃpiʃa, 'ʔɔbə. haʏs, 'zœl.də, 'bal.gən, 'ʃpi: ʧə, 'bɔl.kɪ, 'ʃpi: ʧe, 'by: nə, 'hɔʌn, 'gyɛn,
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<sup>13</sup> Noting the first character of the POP is more specific than expected. This is intended and –although it could easily be adapted to “only mark first generalized character”– it makes very much sense for cases like *Ei* (‘egg’).

	<p>'bal.kŋ, 'd̥ʒaʷ.lət, 'bœn, 'ʃpɔ̄ə, 'ʃpɪçə, 'ʔūə.bə.haʷs, 'ʔūnə.dak, 'bəl.kən, 'dax.lɔ̄ʷ.kən, 'by:.dn̄s, 'ʔūnən.'dakə, 'bȳən, 'bȳə.dn̄, 'ʔun.dəm da:k, 'bɔ̄gn, 'balk, 'da:.bɔ̄dn̄, 'ʔo:l.den, 'dak.bȳə.dn̄, 'bo:.ən, 'by:̄ə.dn̄, 'ha:.nəlt, 'bɔ̄dn̄, 'dak.bo:.dən, 'by:̄ə.nən, 'zœla, 'būə.dn̄, 'ʃpaɪ.ʃə, 'daʷ.bo:m, 'ʔo:l.de, 'ʔo:lə, 'bōə.dn̄, 'by:̄ən, 'zœləɾ, 'dak.ka:.mɛ, 'ʔɔ̄ləm, 'būə.dn̄, 'baɫə.kə, 'dak.bɔ̄nn̄, 'kʰɛɫə, 'dax.stu:.bə, 'ʃpi:.fɛx, 'ʃpaɪ.çə, 'ʃpɪts̄.bɔ̄nn̄, 'būɾə, 'ʃpɪʃə, 'ʃpɪʃɔ̄ə, 'dak.bɔ̄dn̄, 'būdn̄, 'zɔ̄lə, 'sœɫə, 'daʷa:.mɛ, 'bœ:n, 'bœ:.dn̄, 'bȳə.nə, 'doen.t̄sn̄, 'zɔl.de, 'ʔūnəm.'da:.kə, 'bo:.rə, 'di:.ʃn̄, 'dak.bɔn, 'bo:.dən, 'ʔo:n.dɔx, 'ʃpɪʒə, 'spai.çə, 'byn̄.ʃən, 'da:k.bo:.dn̄, 'ʃpe:.çə, 'ʔūɾə, 'zœlə, 'dax.bōə.dn̄, 'bal.k'ŋ, 'dax.bo.dn̄, 'da:k.ʷaʷm, 'kʰa:.mɛ, 'dax.jə.ʃɔs, 'dax.gamɛ, 'ʃpaɪ.çə, 'ʃpɛɪ.çə, 'ka:.mɛn, 'dak.bōənn̄, 'dax.bø:v, 'da:k.būɔ̄n.dn̄, 'da:x.kaməɪ, 'dak.bo:.dn̄, 'dak.būə.dn̄, 'baɫ.k'ŋ, 'ʔɔ̄ə.vix, 'ʃpaɪ.zə, 'ʃpɪçə, 'ʃpaɪ.çn̄, 'ʃpaɪ.jə, 'ʃpaɪ.çə, 'būə.dn̄, 'bəl.gən, 'dak.būə.dn̄, 'dax.bo:.d'ŋ, 'ʃpɪ.çə, 'ʃpɪ.çə, 'dax.bɔ̄dn̄, 'hɔ̄ɪ.bo:.dn̄, 'bal.gə, 'dax.bōə, 'ha:.nə.bal.kən, 'dax.ka:.mɛ, 'ʃpɪçə, 'ʃpɪʃənn̄, 'ʃpɪçə, 'bīən, 'baɫ.kŋ.ru:m, 'ʃpi:.fɛx, 'ʃpi:.ʃə, 'dak.bo:.dn̄, 'ʃpɪçə, 'ʃpɪts̄.bo:m, 'dak.k:a.mɛ, 'dak.bɔ̄dn̄, 'ʃpaɪçə, 'ʃpɪ.çə, 'ba:.kŋ, 'zœɫ.de, 'dak.kʰɔ̄mɔn, 'dak.būɔ̄dn̄, 'ʃpɪ.çə, 'bāənn̄, 'dak.bœn, 'ʃpɪçəl, 'dak.kɔ̄mɔn, 'da:x.kamɛ, 'gȳən, 'dax.būɾə, 'dax.būə, 'dax.būə, 'ʃpɪ.çə, 'bȳənn̄, 'da:.bo:.dn̄, 'lyn̄p̄f, 'lœɪf, 'veɪm, 'dax.būɾə, 'dax.bo:.dən, 'zœɫə, 'baɫ.kən, 'būɔ̄d'ŋ, 'bɔn, 'ʔup.kamɛ, 'dak.bo:.dən, 'ka:.mɛ, 'dax.bal.kən, 'ha:n.ʔo:lt, 'ha:n.ʔolt, 'by:n, 'baʷ.bm, 'zœl.də, 'dax.būə.bm, 'ʃpi:.çə, 'dax.bɛɟl.dn̄, 'ʃpaɪ.zə, 'zœlə, 'ʃpaɪ.çə, 'zɔ̄lə, 'da:k.bo:m, 'hai.bo:.dən, 'da:k.bœ:n, 'ʔūnə 'dak, 'da:x.ka:.mɛ, 'lof, 'dax.ka:.mɛ, 'man.za:də, 'dax.būə.dn̄, 'ʃpɛɪ.çə, 'dak.kamɛ, 'bȳən, 'dax.bo:n, 'gɛɔ̄.ɔ̄.pə.bal.kən, 'dakʰ.ka:.mɛ, 'dax.bɔ̄dn̄, 'ʃpaɪ.zə, 'by:̄ən, 'dax.būɔ̄n, 'ʔo:.də, 'ʃpaɪ.çə, 'ʃtro.bal.kən, 'da:.ka:.mɛ, 'zœ:l.de, 'zœ:lə, 'taʷ.bn̄.ʃlax, 'ʃpaɪ.ʃə, 'dax.bœn, 'zɪlə, 'hi:lə, 'ʔūə.və.nə, 'dak.būə.dn̄, 'hɔ̄ɪ.bo:.dn̄, 'bɔ̄.ə</p>
<p>Level 0 (POPs)</p>	<p>BALKEN, BOLLEKEN, SCHPISCHER, SCHPAISCHE, SCHPEESCHE, BALGE, BALKNG, BALKN, BÜÖN, SAULER, SULLE, BUU-ADN, SCHPISCHE, BALKE, SCHPIIKER, DAKROUM, DACHSCHROAT, BALLEKEN, BOODN, BORRE, SÜLNER, DACHBOODN, ULLAN, UNGAN, ULLERN, ULLEN, SCHPAISCHER, OGGELN, SCHPÄESCHER, SÖLLER, BOODE, OLLARN, BÖÖ-N, SCHPAIJER, DAAKBÜADN, SÖLLER-IS, OLLAN, DACHBORREN, HULDAN, ULDAN, LÖÖF, SPIICHER, SCHPAIJE, SÖLDER, BÜNNE, BALGNG, BÖDDN, BÜÜEL, SPISCHER, SCHPISCHL, SCHPIISCHER, SCHPISCHA, OBBEHAUS, BALGEN, SCHPIICHE, BOLKN, BÜÜNE, HOLLAN, GÜAN, DJAULET, BÖN, SCHPORRE, UEBEHAUS, UNNEDAK, BOLKEN, DACHLOUKEN, BÜÜDNS, UNNANDAKKE, BÜEN, BÜEDN, UNDAM DAAK, BOAN, BALK, DAABODDN, OOLDAN, DAKBÜEDN, BOO-EN, BÜÜEDN, HAANELT, BODDN, DAKBOODEN, BÜÜENEN, SÖLLA, BUEDN, DACHBOOM, OOLDER, OOLE, BOADN, BÜÜEN, DAK-KAAMER, OLLERN, BUODN, BALLEKE, DAKBON´, KELLER, DACHSTUUBE, SCHPIISCHACH, SCHPITZBON´, BURRE, SCHPISCHOA, DAKBODDN, BUDDN, SOLLER, DAKKAAMER, BÖÖN, BÖÖDN, BÜENE, DÖNZN, SOLDER, UNGAMDAAKE, BOORE, DII-LN, DAKBON, BOODEN, OONDOCH, SPAISCHE, BÜNSCHEN, DAAKBOODN, SCHPEESCHER, URRE, SÖLLE, DACHBOADN, DACHBODN, DAAKRAUM, KAAMER, DACHJESCHOS, DACHGAMMER, SCHPAICHE, SCHPEICHE, KAAMAN, DAKBOEN, DACHBÖÖW, DAAKBUONDN, DAACHKAMMER, DAKBOODN, DAKBUODN, OAWICH, SCHPICHER, SCHPAICHN, SCHPAICHER, BOLGEN, DACHBODDEN, HEUBOODN, DACHBOE, HAANEBALKEN, DACHKAAMER, SCHPISCHERN, SCHPICHE, BIEN, BALKN-RUUM, SCHPIISCHECH, SCHPISSER, SCHPITZBOOM, DAK-KKAMER, BAAKN, DAK-KOMMON, DAKBUODDN, BARREN, DAKBÖN, SCHPÜSCHEL, GÜEN, DACHBURRE, DACHBUA, SCHPIICHER, DABOODN, LÜNPF, LÖÜF, WEIM, DACHBORRE, DACHBOODEN, BON, UPKAMMER, DACHBALKEN, HAAN-OOLT, HAAN-OLT, BÜÜN, BAUBM, SÖLDE, DACHBUOBM, SCHPIISCHE, DACHBEALDN, DAAKBOOM, HAIBOODEN, DAAKBÖÖN, UNNA DAK, DAACHKAAMER, LOF, MANSADE, DACHBUODN, SCHPEISCHE, DAK-KAMMER, DACHBOON, GROUPEBALKEN, DACHBODDN, BÜÜAN, DACHBUON, OODE, SCHPAICHA, SHTROBALKEN, DAAKAAMER, SÖLDER, SÖLER, TAUBN-SCHLACH, SCHPAISCHER, DACHBÖN, SÜLLER, HIILE, UEWENE, DAKBUEDN, HEUCHBOODN, BOU-E</p>

Level 1	BzLKzN, BzLKN, SvLLzR, EPz_ΣzR, BzLKI], Bv_N, EPvΣΣzR, SvLDzR, EPz_Σz, DzXBh = DN, SvLLz, Bh = DN, hLLzN, EPvΣΣz, BvN, BzLGz, EPvXXzR, BzLKz, Bv = _N, EPz_Çz, EPz_ÇzR, Lv = F, BhDDN, Bh_DN, ShLDzR, DzXBhRRz, DzK-Kz = MzR, ShLLzR, EPvÇzR, EPvΣz, EPz_Jz, EPv = ΣzR, DzKBh_DN, EPvΣzR, BzLLzKzN, BhRRz, hLLzRN, Bh = Dz, h = LDzN, h = Lz, DzKBhDDN, Bv = N, DzKBh = DN, DzXBhDDzN, EPvXXz, DzXBh = N, BhLLzKzN, EPz_JzR, EPvΣL, Bv = Nz, Gv_N, BzLK, Bv = _DN, DzKBh = DzN, h = LDzR, EPv = ΣzX, Bv_Nz, Bh = Rz, DzXBh_DN, Kz = MzR, Dz = XKzMMzR, DzXBh_, DzXKz = MzR, EPvÇz, DzK-KhMMhN, EPv = ÇzR, DzXBzLKzN, Bz_BM, EPv = Σz, EPz = Jz, EPz = Σz, Sz_LzR, ShLLz, Bh = -_DN, EPv = KzR, DzKRh_M, DzXERh_T, SvLNzR, hI]I]zN, hGGzLN, EPv_ΣzR, Bv = -N, Dz = KBv_DN, SvLLzR-_S, DzXBhRRzN, HhLDzN, hLDzN, SPv = ÇzR, BvNNz, BzLGI], BvDDN, Bv = _L, SPvΣzR, hBBzHz_S, BzLGzN, EPv = Çz, BhLKN, HhLLzN, DJz_LzT, SPhRRz, h_BzHz_S, hNNzDzK, BhLKzN, DzXLh_KzN, Bv = DNS, hNNzNDzKz, Bv_DN, hNDzM Dz = K, Bh_N, Dz = BhDDN, DzKBv_DN, Bh = -_N, Hz = NzLT, Bv = _NzN, DzYBh = M, BzLLzKz, DzKBhN', KzLLzR, DzXSTh = Bz, EPvTZBhN', EPvΣΣh_, DzKKz = MzR, Bv = DN, DvNZN, hI]I]zMDz = Kz, Dv = -LN, DzKBhN, Bh = DzN, h = NDhX, SPz_Σz, BvNΣzN, Dz = KBh = DN, EPz = ΣzR, hRRz, DzXBhDN, Dz = KRz_M, DzXJzΣhS, DzXGzMMzR, Kz = MzN, DzKBh_N, DzXBv = W, Dz = KBh_NDN, h_WvX, EPz_ÇN, BhLGzN, Hz_Bh = DN, Hz = NzBzLKzN, EPvΣΣzRN, BzLKN-Rh = M, EPvSSzR, EPvTZBh = M, DzK-KKzMzR, EPz_ΣΣzR, Bz = KN, DzKBh_DDN, BzRRzN, DzKBvN, EPvΣΣzL, KzMMz, v_MSzL, DzBh = DN, LvNPF, Lv_F, Wz_M, DzXBh = DzN, BhN, hPKzMMzR, Hz = N-_ = LT, Hz = N- LT, SvLDz, DzXBh_BM, DzXBz_LDN, Dz = KBh = M, Hz_Bh = DzN, Dz = KBv = N, hNNz DzK, Dz = XKz = MzR, LhF, MzNSz = Dz, DzK-KzMMzR, GRh_PzBzLKzN, DzXBhDDN, DzXBh_N, h = Dz, Bz = LKzN, SvLLh, ΣTRhBzLKzN, Dz = Kz = MzR, Sv = LDzR, Sv = LzR, Tz_BN-ΣLzX, EPz = ΣzR, DzXBvN, Hv = Lz, h_WzNz, Hz_ÇBh = DN, Bh_-
Level 2	BzLK, SvLz, EPvΣz, EPz_Σz, BhDN, Bv_N, hLz, BvN, SvLDz, KzMz, Bh_DN, hRz, EPz_Çz, hDz, EPvXz, BzLGz, EPvÇz, hLDzR, LvF, EPz_Jz, BhN, hLDzN, Bv_DN, Bh_N, BzLzKz, BvDN, DzXBh_, BhLzKzN, EPzΣz, EPvΣL, Gv_N, DzKhMhN, HzN_LT, Bz_BM, EPzJz, Sz_LzR, EPvKzR, DzKRh_M, DzXERh_T, SvLNzR, hI]zN, hGzLN, EPv_ΣzR, SPvÇzR, BzLGI], Bv_L, SPvΣzR, hBzHz_S, BhLKN, DJz_LzT, h_BzHz_S, hNzDzK, BhLKzN, DzXLh_KzN, hNzNDzKz, hNDzM DzK, HzNzLT, DzYBhM, KzLzR, DzXSThBz, EPvTZBhN', EPvΣh_, DvNZN, hI]zMDzKz, DvLN, hNDhX, SPz_Σz, DzKRz_M, DzXJzΣhS, DzXGzMzR, DzXBvW, h_WvX, EPz_ÇN, BhLGzN, EPvSzR, EPvTZBhM, BzKN, BzRzN, v_MSzL, LvNPF, Lv_F, Wz_M, DzXBz_LDN, DzKBhM, hNz DzK, LhF, MzNSzDz, SvLh, Tz_BNΣLzX, HvLz, h_WzNz, Bh_
Level 3	P_LK, S_L_, EP_Σ_, EP_Σ_, P_N, P_DN, P_N, S_LD_, K_M_, EP_Ç_, P_DN, P_R_, EP_Ç_, _L_N, P_D_, L_F, EP_J_, P_L_K_, _LD_N, _L_RN, H_N_LD, _L_, D_ÇP_, P_PM, D_KR_M, EP_ΣL, _P_H_S, K_N, _LD_R, EP_J_, H_L_, S_L_R, EP_K_R, D_ÇER_D, S_LN_R, _I]_N, _K_LN, H_LD_N, SP_Ç_R, P_L, SP_Σ_R, DJ_L_D, _N_D_K, D_ÇL_K_N, _N_ND_K_, _ND_M_D_K, D_ÇP_M, K_L_R, D_ÇSD_P_, EP_DZP_N', D_NZN, _I]_MD_K_, D_LN, _ND_Ç, SP_Σ_, _R_, D_ÇJ_Σ_S, D_ÇP_F, _F_Ç, EP_ÇN, EP_S_R, EP_DZP_M, P_KN, _MS_L, L_NPF, L_F, F_M, D_KP_M, _N_D_K, M_NS_D_, _D_, D_PNΣL_Ç_, _F_N_, P_
Level 4	P_L, EP_Σ_, P_N, S_L_, P_DN, EP_Ç_, S_LD_, K_M_, P_R_, _L_N, P_D_, L_F, EP_J_, K_N, D_ÇP_, _LD_N, _L_RN, _L_, P_PM, D_KR_M, EP_ΣL, _P_H_S, _LD_R, SP_Σ_, H_NLD, H_L_, EP_K_R, D_ÇER_D, S_LN_R, _I]_N, _K_LN, H_LD_N, SP_Ç_R, DJ_L_D, _N_D_K, _N_ND_K_, _ND_M_D_K, H_N_LD, K_L_R, D_ÇSD_P_, EP_DZP_N', D_NZN, _I]_MD_K_, D_LN, _ND_Ç, _R_, D_ÇJ_Σ_S, _F_Ç, EP_ÇN, EP_S_R, EP_DZP_M, P_KN, _MS_L, L_NPF, F_M, D_KP_M, _N_D_K, M_NS_D_, _D_, D_PNΣL_Ç_, _F_N_, P_
Level 5	B, Σ, S, D, O, U, H, L, K, G, W, M, T

Table 2: Different types of codes for RWL Dachboden

The codes in Table 1 and Table 2 already represent the final cluster categories, i.e., after mapping complex codes transitively to existing subcodes (see above HEAPSLAUP→LAUP example) and removing

the redundant complex codes. Such a mapping is shown for three levels of *Dachboden* (other words involve fewer mappings, even none, as *Ei*) in Table 3.

Level 2	BhDz→hDz, BhDzN→hDz, BhRz→hRz, BvDNS→BvDN, BvNz→BvN, BvNΣzN→BvN, Bv_Nz→Bv_N, Bv_NzN→Bv_N, BzLGzN→BzLGz, BzLKN→BzLK, BzLKNRhM→BzLK, BzLKz→BzLK, BzLKzN→BzLK, BzLKlJ→BzLK, BzLzKzN→BzLzKz, DzBhDN→BhDN, DzKBhDN→BhDN, DzKBhDzN→hDz, DzKBhN→BhN, DzKBhN'→BhN, DzKBh_DN→Bh_DN, DzKBh_N→Bh_N, DzKBh_NDN→Bh_N, DzKBvN→BvN, DzKBv_DN→Bv_DN, DzKzMz→KzMz, DzXBhDN→BhDN, DzXBhDzN→hDz, DzXBhN→BhN, DzXBhRz→hRz, DzXBhRzN→hRz, DzXBh_BM→DzXBh_, DzXBh_DN→Bh_DN, DzXBh_N→Bh_N, DzXBvN→BvN, DzXBzLKzN→BzLK, DzXKzMz→KzMz, DzXKzMzR→KzMz, GRh_PzBzLKzN→BzLK, HhLDzN→hLDz, HhLzN→hLz, Hh_BhDN→BhDN, Hh_ÇBhDN→BhDN, HznzBzLKzN→BzLK, Hz_BhDzN→hDz, KzMzN→KzMz, ShLDz→hLDz, ShLz→hLz, SvLzR→SvLz, SvLz_S→SvLz, hLDzN→hLDz, hLzN→hLz, hLzRN→hLz, hPKzMz→KzMz, ΣPhRz→hRz, ΣPvΣzL→ΣPvΣz, ΣPvΣzRN→ΣPvΣz, ΣPvΣzX→ΣPvΣz, ΣTRhBzLKzN→BzLK
Level 3	D_KP_DN→P_DN, D_KP_D_N→P_D_, D_KP_N→P_N, D_KP_N'→P_N, D_KP_DN→P_DN, D_KP_N→P_N, D_KP_NDN→P_N, D_K_M_→K_M_, D_K_M_N→K_M_, D_P_DN→P_DN, D_ÇK_M_→K_M_, D_ÇK_M_R→K_M_, D_ÇP_DN→P_DN, D_ÇP_D_N→P_D_, D_ÇP_LK_N→P_LK, D_ÇP_N→P_N, D_ÇP_R_→P_R, D_ÇP_R_N→P_R, D_ÇP_DN→P_DN, D_ÇP_LDN→D_ÇP_, D_ÇP_N→P_N, D_ÇP_PM→P_PM, H_L_N→H_L, H_N_P_LK_N→P_LK, H_P_DN→P_DN, H_P_D_N→P_D_, H_ÇP_DN→P_DN, KR_P_P_LK_N→P_LK, K_M_N→K_M_, P_DNS→P_DN, P_D_N→P_D_, P_LKN→P_LK, P_LKNR_M→P_LK, P_LK_→P_LK, P_LK_N→P_LK, P_LKlJ→P_LK, P_L_K_N→P_L_K, P_N_→P_N, P_NΣ_N→P_N, P_R_N→P_R, P_N_→P_N, P_N_N→P_N, S_L_R→S_L, S_L_S→S_L, ΣDR_P_LK_N→P_LK, ΣP_R_→P_R, ΣP_Σ_L→ΣP_Σ_, ΣP_Σ_RN→ΣP_Σ_, ΣP_Σ_→ΣP_Σ_, ΣP_Σ_Ç→ΣP_Σ_, _PK_M_→K_M_, _P_H_S→_P_H_S
Level 4	D_KP_DN→P_DN, D_KP_D_N→P_D_, D_KP_N→P_N, D_KP_NDN→P_N, D_KP_N'→P_N, D_K_M_→K_M_, D_K_M_N→K_M_, D_P_DN→P_DN, D_ÇK_M_→K_M_, D_ÇK_M_R→K_M_, D_ÇL_K_N→K_N, D_ÇP_DN→P_DN, D_ÇP_D_N→P_D_, D_ÇP_F→D_ÇP_, D_ÇP_LDN→D_ÇP_, D_ÇP_LK_N→K_N, D_ÇP_M→D_ÇP_, D_ÇP_N→P_N, D_ÇP_PM→P_PM, D_ÇP_R_→P_R, D_ÇP_R_N→D_ÇP_, H_L_N→H_L, H_N_P_LK_N→K_N, H_P_DN→P_DN, H_P_D_N→P_D_, H_ÇP_DN→P_DN, KR_P_P_LK_N→K_N, K_M_N→K_M_, P_DNS→P_DN, P_D_N→P_D_, P_LK→P_L, P_LKN→P_L, P_LKNR_M→P_L, P_LK_→P_L, P_LK_N→P_L, P_LKlJ→P_L, P_L_K_→P_L, P_L_K_N→P_L, P_N_→P_N, P_N_N→P_N, P_NΣ_N→P_N, P_R_N→P_R, S_L_R→S_L, S_L_S→S_L, ΣDR_P_LK_N→K_N, ΣP_R_→P_R, ΣP_Σ_L→ΣP_Σ_, ΣP_Σ_RN→ΣP_Σ_, ΣP_Σ_Ç→ΣP_Σ_, _PK_M_→K_M_

Table 3: Remappings of codes of Dachboden

#### 4.5 DPA: application

Recall that the purpose of POP clustering is to arrive at a smaller set of POP types in order to obviate cluttered maps and corresponding visual confusion, and to allow for intuitive use and easy interaction with the ‘Speaking DMW’. Basically, this is realized by letting the user select the granularity level he/she is interested in, thereby reducing the complexity of presentation and interaction. With a level being set, the POP types to be shown in the legend can then be specified, and the level of detail of the preview map can be determined. This is implemented as follows.

First, the clusters of a level (as well as their POPs) are sorted according to their relevance, i.e., the frequency of their POP *instances*. In the legend, the clusters can then be offered in decreasing order, starting with the most relevant one. Second, each cluster is *termed* to be easily identifiable, not just by the set of POPs it represents (which is shown on mouseover of the cluster field). Unfortunately, it is not

possible to come up with an automatic procedure to *generate* a term for a cluster (based on its POPs). However, simply *using* its most relevant POP as its label suffices for this purpose, as the DPA results in distinctive clusters by definition. Third, we assign each of the *twelve* highest ranked clusters of a level one of a set of twelve maximally contrastive colours (correspondingly ranked by their salience). While the number is arbitrary and debatable, the use of colours as opposed to specific symbols is supposed to make the POP types easily recognizable (note that we offer a secondary colour palette for people with disabilities in colour perception) and to avoid visual confusion. To signify data distribution and diversity on the preview map, we mainly use pie charts (see below). They can be regarded as the only option for the signification of type clusters on our preview maps, both due to the large number of explored places, and to the fact that type diversity per place is frequent for automatically categorised data.

To exemplify the application of the DPA, Figure 7 and Figure 8 show the menus of decreasing granularity level aligned for comparison, each with their clickable, coloured, and typed fields corresponding to the clusters. Recall that the up to twelve coloured fields are ordered by the number of corresponding variants (further gray-coloured fields/clusters not shown here).

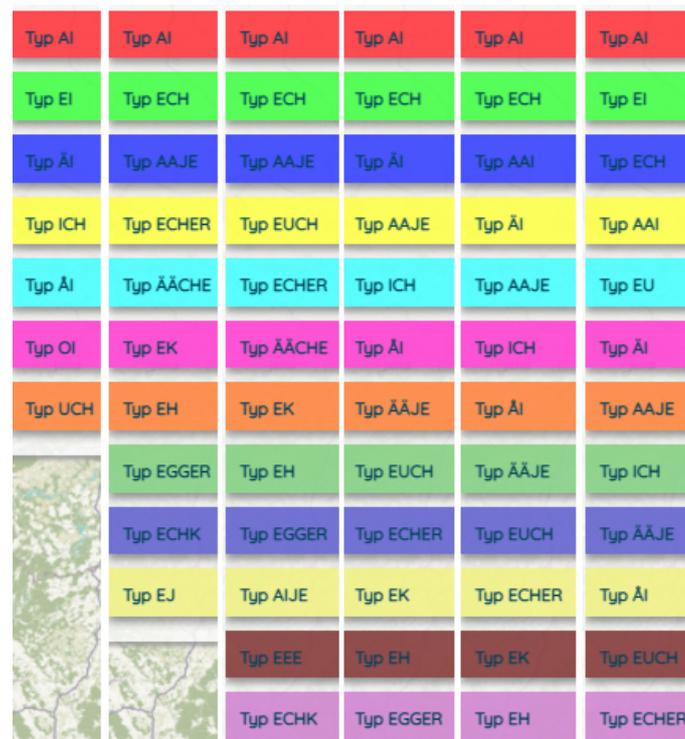


Figure 7: Clickable variant type fields in the legend for the granularity levels of Ei (5 to 0)

It can easily be seen in Figure 8 that with the “Typ Balken” fields always ranked highest, they correspond to the most frequent clusters (probably different in each case), while the ranks of other types change. For example, type BÜEN (level 4, second column, rank three, darkblue) is ranked higher than the same type on level 3 (third column, rank five, lightblue). This is due to the fact that while vowel aspects are conflated on level 4, level 3 distinguishes vowel change (diphthongs) from non-change (monophthongs), hence the level-3 differentiation of types BÜEN and BÖN (rank seven, darkorange), both with smaller frequency values.

Typ BALKEN	Typ BALKEN	Typ BALKEN	Typ BALKEN
Typ SCHPAISCHER	Typ SCHPAISCHER	Typ SÖLLER	Typ SÖLLER
Typ SÖLLER	Typ BÜEN	Typ SCHPISCHER	Typ SCHPISCHER
Typ DACHBOODN	Typ SÖLLER	Typ SCHPAISCHER	Typ SCHPAISCHER
Typ OLLAN	Typ DACHBOODN	Typ BÜEN	Typ DACHBOODN
Typ ULLAN	Typ SCHPISCHER	Typ DACHBOODN	Typ BÜEN
Typ HULDAN	Typ SÖLDER	Typ BÖN	Typ OLLAN
Typ LÖÖF	Typ DAK-KAAMER	Typ SÖLDER	Typ BÖN
Typ KAAMER	Typ DACHBURRE	Typ SCHPISCHER	Typ SÖLDER
Typ GÜAN	Typ OLLAN	Typ BUODN	Typ DAK-KAAMER
Typ WEIM	Typ BOODE	Typ DAK-KAAMER	Typ DACHBURRE
Typ MANSAADE	Typ LÖÖF	Typ DACHBURRE	Typ SCHPAISCHER

Figure 8: Clickable variant type fields in the legend for the granularity levels of Dachboden (5 to 2)

Figure 9 depicts a single POP type field on mouse-over (grayed out *Dachboden* cluster field on level 2). The cluster is determined by the common code KzMz (of KAMA), and named by the most frequent POP DAK-KAAMMER (the overall number of occurrences of cluster variants given in brackets).

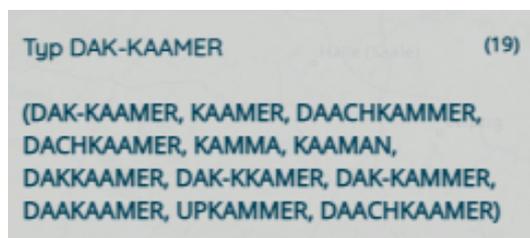


Figure 9: A level-2 cluster for Dachboden

Observe that no principles of dialectology are involved in this multi-layered clustering scheme. Apart from the fact that none were available at the time of its development, reaction time of the map interface is essential for user experience (computing level info and corresponding map presentation of the data on level choice). It can be expected that any more sophisticated scheme (for example, considering location aspects of variants for categorization) would slow down performance noticeably.

## 5 Aspects of Preview maps

There are a number of requirements regarding content (presentation), interaction, and (web) technology to be considered in implementing the map interface. In the following, these requirements and their corresponding solutions are discussed.

## 5.1 Content (presentation)

At the core of the DMW system, there is the mass of diverse dialect(ological) data, and the requirement to tailor its presentation to different *user* classes (lay people and experts). More specifically, there are object and meta data of exploration and analysis, some of which are relevant for the map interface. Primarily, the preview maps are supposed to show the analysis data for some exploration item (a RWL), and to provide the facility to hear the correspondingly cutted audios (the observants of the RWSes) of the informants at some explored place.

Within this basic functionality of the “Speaking DMW”, one has to distinguish the audio-visual presentation of variants of words via the POP mechanism, and the possibility to select and hear (multiple) Wenker sentences. In the map interface, *word maps* and *Wenker maps* are offered for this distinction, respectively (see Figure 10 and Figure 11). Both figures show the removable central half-transparent map query menus and the popup-windows containing the wav/mp4 players at a certain mouse-clicked place. The map types are different in that Wenker maps lack the legend of word maps. Also, while a word map popup contains players for the variants of each person (i.e., audio on demand), playing the Wenker sentences starts on click, and as a looped sequence of all wavs/mp4s of the selected Wenker sentences, and of all persons at that place (navigation backward and forward is offered).

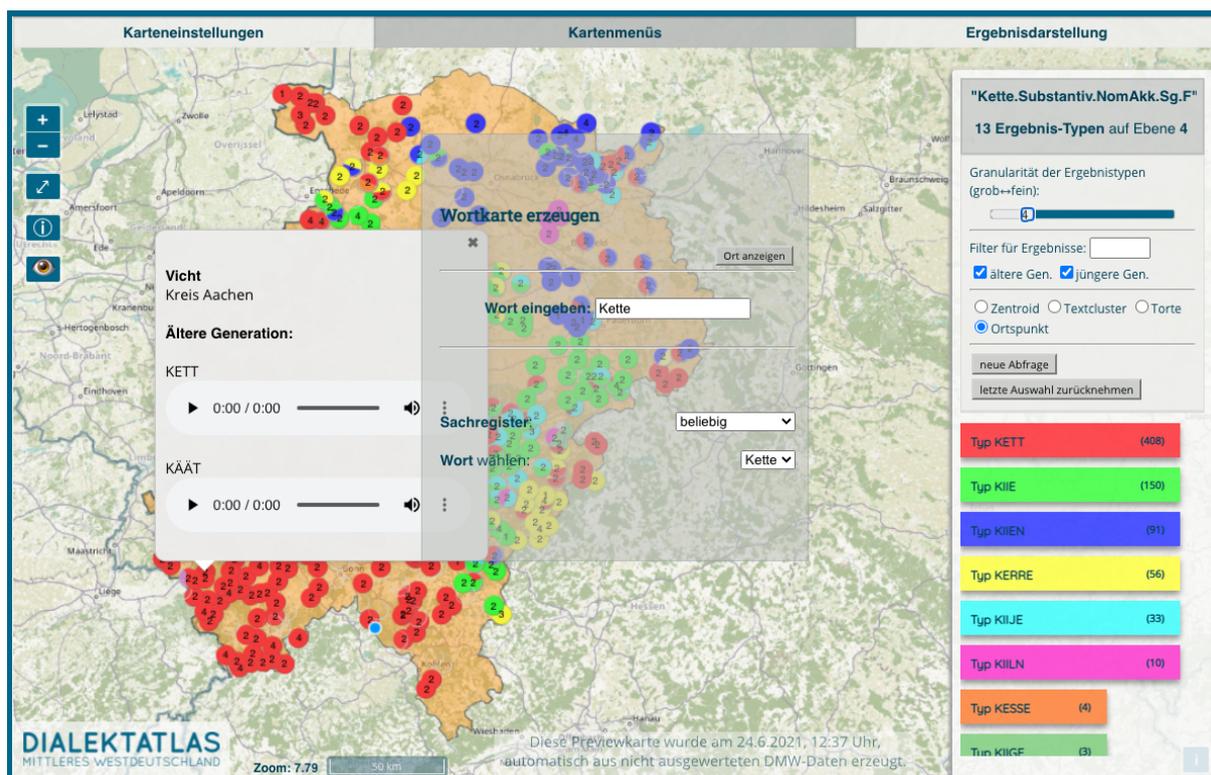


Figure 10: Word map of Kette

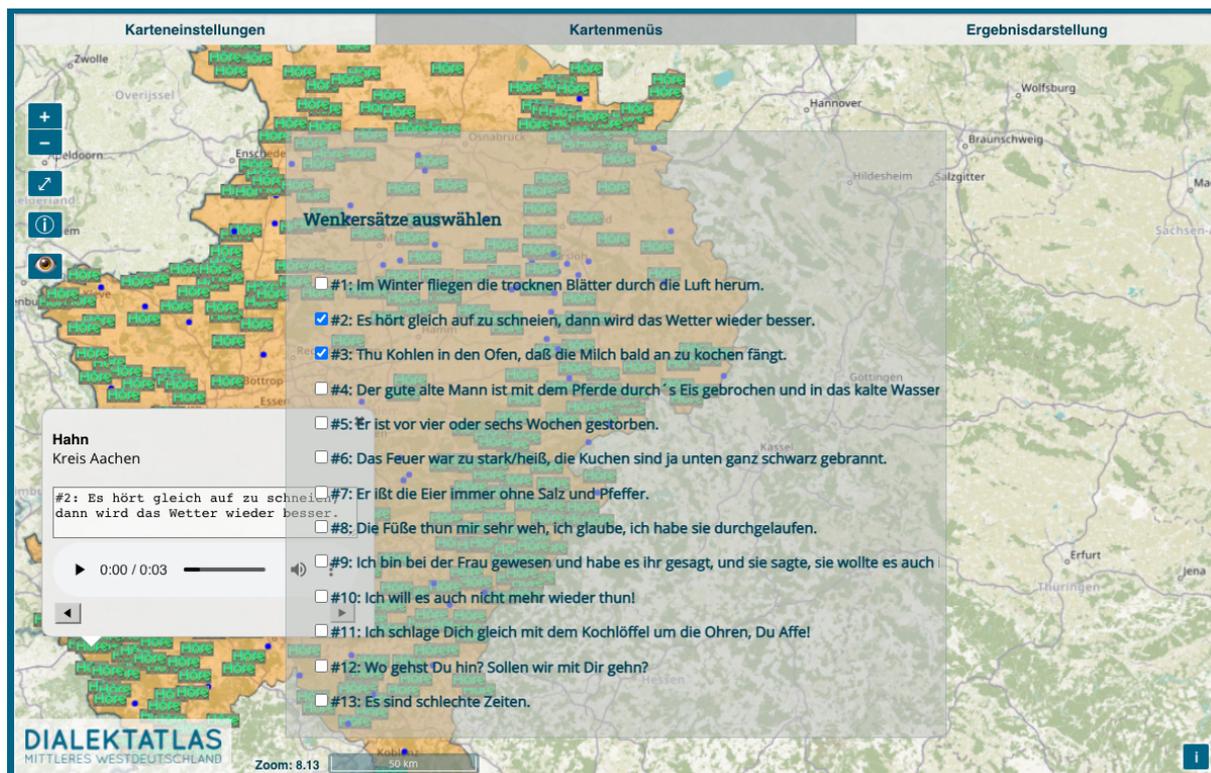


Figure 11: Wenker map of selected Wenker sentences

It is also possible to construct several word maps at the same time, and to compare the corresponding distributions on a so-called *comparison map* (“Vergleichskarte”). Figure 12 shows such a display, in which (only) occurrences containing *sk* of two words (*Tasche*, *Flasche*) are mapped. In the expert version, phenomenon-related analysis data, as well as dialectometric comparison data, are presented on corresponding (phenomena/dialectometric) maps. In the legend of a comparison map, the variant type fields do not show POP( type)s, but the specifications of the query for the corresponding map-to-be-compared (i.e., the list of option choices made).

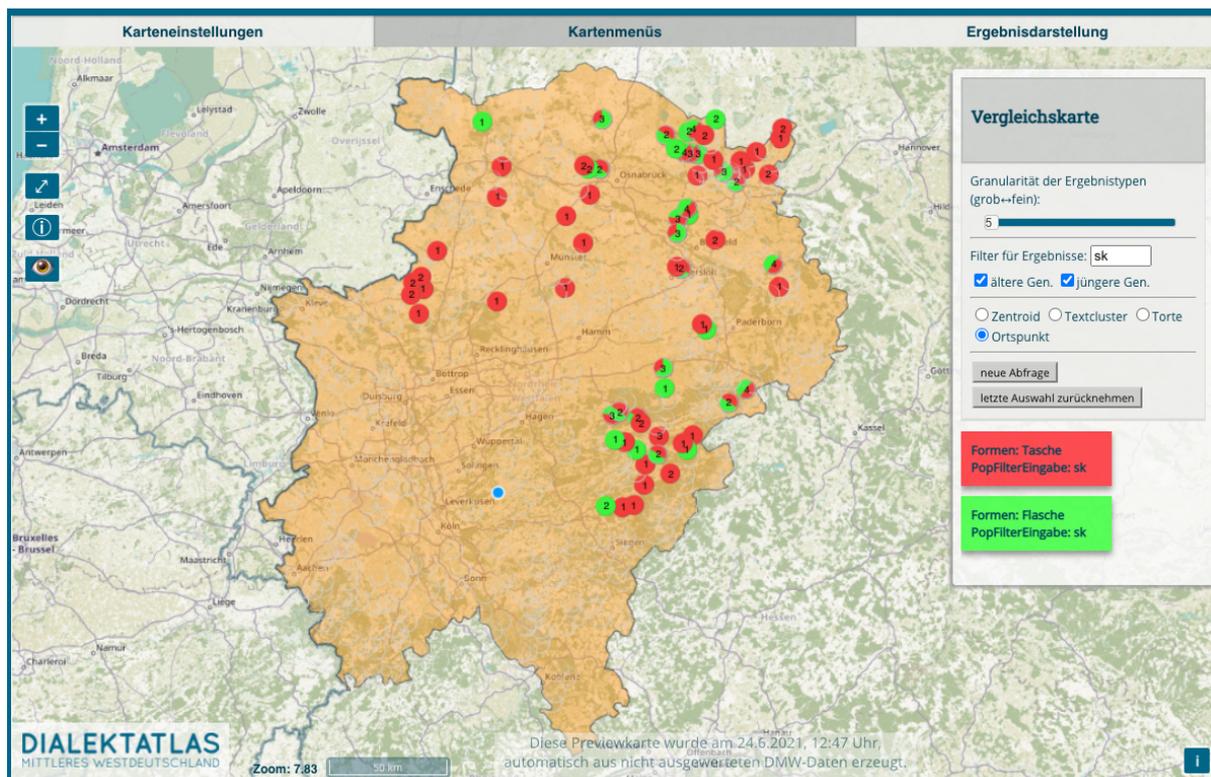


Figure 12: Comparison map

The most prominent dialectometric type is a reference point map, which codes distances between variants of a clicked-on reference cell and each other cell as colours on a linear green-red scale (close to distant).<sup>14</sup> There are two mechanisms to ensure adequacy of this scale for the probable case of very different variants (where red would be the dominant colour). First, the sorted domain of values is cut off at some point, and outliers receive the maximum value (“clamping”), which better reflects the differences in the proximal range of values, while only conflating different distant values. Second, reference point comparison is performed for the places of the browser window’s content, i.e., the currently “visible” area. Different from a global process, this better mirrors the finer distinctions of closer related variants in zoomed-in situations. Figure 13 displays such a reference point map for *Kette*, showing “regions of similarity”.

<sup>14</sup> Since each place typically has more than one, and potentially different, variants, the smallest value (i.e., of the closest variants) is selected. As to the empty/transparent cells, data for the corresponding place are either not yet analyzed, or have been sorted out as invalid or irrelevant.

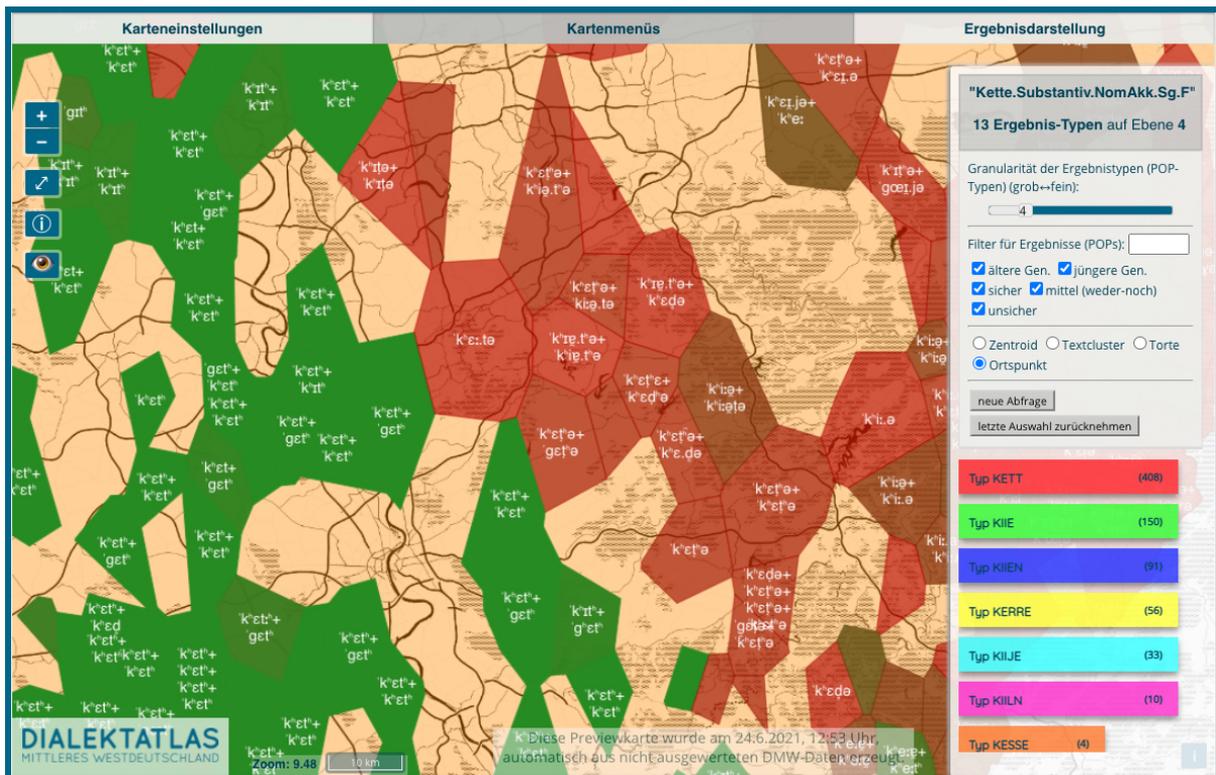


Figure 13: Reference point map

In general, meta data are used to restrict data presentation, for example, to some age group, or to some certainty-of-transcription level (the POP mechanism can be regarded as another case in point, with the index terms representing similarity data about the variants).

For the presentation of our mass data of variants, it is necessary to guarantee the *perceptibility* of data variation and distribution. As to *data variation*, its confusion is prevented by the POP mechanism, with which different similarity-based clusters of the data can be computed (and selected) on six levels of granularity with the DPA described above. By starting with level 5, this corresponds to having a coarse overview at the beginning.

The perception of *data distribution* is facilitated by four different kinds of *locational clusters* and their distinctive symbolization on preview maps, and by offering four corresponding options of presentation. All of them share the use of *colour* for the symbolization of variant types, as the use of specific symbols would easily lead to visual cluttering for higher numbers of types (and is therefore forbidden in the face of our data variety).<sup>15</sup>

The first option is *place-oriented data clustering* (“Ortspunktdarstellung”), according to which the data of a place (from up to four persons) are clustered and presented as a small, point-like pie chart (the pie

<sup>15</sup> The perception of the (up to twelve) colours on word maps used to distinguish types is enhanced by the selection of high-contrastive ones for this purpose. This use of colours therefore is a basic feature of the DMW system, and marks our secondary colour palette as a stopgap for people with disabilities in colour perception.



Another means to allow for better perceptibility of the data is *data selection for presentation*. The map interface offers three facilities to do that. The first is *momentary variant type selection* by the use of Open Layers' *heat maps*. They are generated if a user does a mouseover on a variant/POP type field in the legend. In a heat map, the places of the selected POP type are foregrounded with a blurred colour scheme (red core, yellow inner border, green outer border). In the case of neighbouring places, this results in a confluent, intensified red colouring, highlighting that region (and therefore marking relative distribution). At the same time, all other information is hidden (compare Figure 15 and Figure 16). On mouseout, everything is restored.

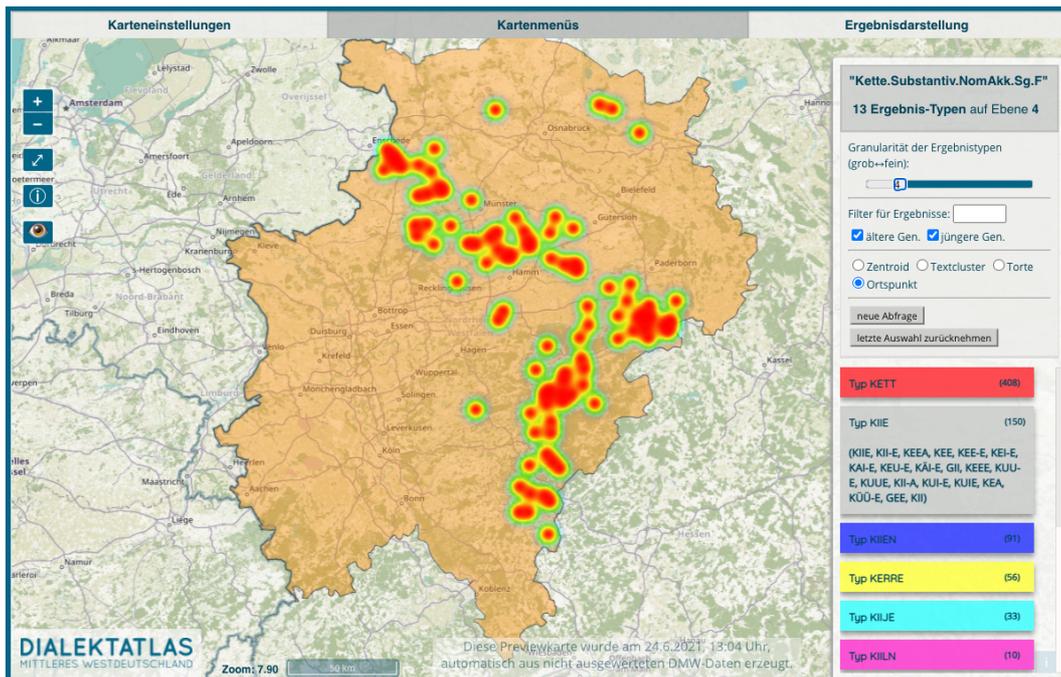


Figure 15: Heatmap of POP type KIIE of Kette (level 4)

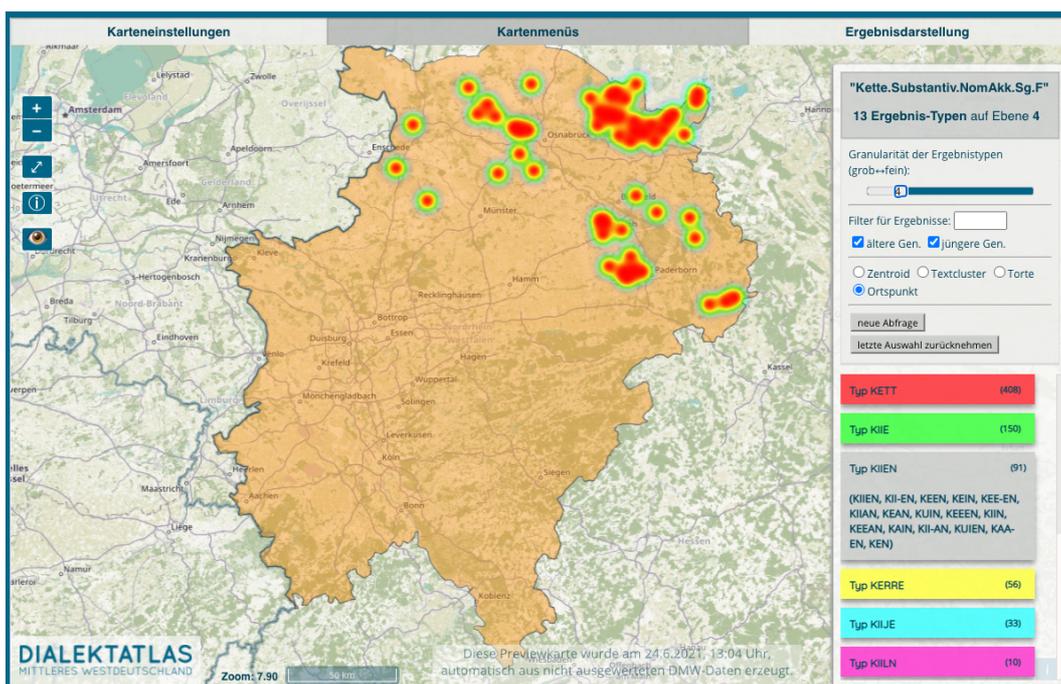


Figure 16: Heatmap of POP type KIEN of Kette (level 4)

The second is *permanent variant type selection* by double-clicking a POP field in the legend, given some granularity level. In this case, presentation is restricted to the data corresponding to the current-level POP type in question. This is especially useful for the investigation of a certain class of variants, before lowering the granularity level (again). The selection remains active until it is explicitly taken back by clicking on “letzte Auswahl zurücknehmen” (“Undo last selection”).

The third aspect is *filtering*. This is done by entering regular expressions in the corresponding field of the legend, which are used to filter the set of POPs before (re)application of the DPA. Filtering can be performed on any level of granularity (see Figure 17 for a *Kette* word map with the filter set to “ends with a ‘n’” on granularity level 4).

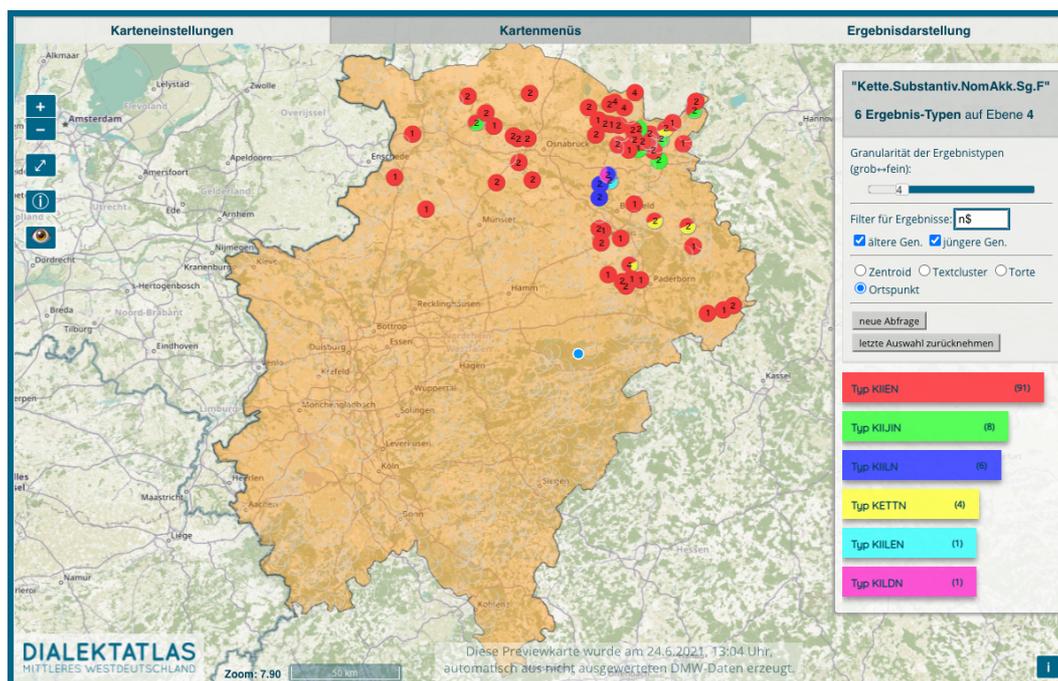


Figure 17: Word map *Kette* restricted to variants ending with “n”

Needless to say that these means of dealing with the perceptibility of data variation and distribution can be used in combination. For example, by setting a granularity level, clicking on a POP type field, setting a lower granularity level, and finally entering a filter expression. By undoing last actions and entering a different part/path of the possible options, this procedure corresponds to *exploring* the distribution of some RWL’s variants.

## 5.2 Interaction

There are some requirements regarding user interaction in the map interface. First of all, this includes aspects of *usability* and ergonomics, given the two basic classes of users (lay people, experts): especially, an intuitive, easy handling of the interface, that should not only be (visually) parsimonious, but also self-explanatory at best. Then, the map interface should allow *different perspectives and choices*, as well as individual preferences for one or the other. Finally, interaction should also be *explorative*. This requirement for visualization applications can be described by the following steps of visual analytics (Keim et al. 2010): Provide *overview* (most important things first); offer *intuitive options* (for example,

zooming/filtering, restricting, focusing, navigating); provide *details on demand*; show *relationships*; *easy switching* between aspects to be displayed. We tried to meet these needs as follows.

First, there is no distinction between a query page (specifying the type of data to be presented) and a map page (which was the case in the small precursor project SiSAL, see Solau-Riebel/Vogel 2013-2016), simplifying interaction. Instead, the centered query menus –being the currently focused elements of interaction– are always displayed *on top* of the geo-centered map and data layers (even with a graphical selection menu on top of the standard query menu, see Figure 18). Likewise, removing the top level corresponds directly to falling back to the next important lower level, or established state of presentation. Interaction is further facilitated by offering additional shortcuts to close menus and popups.

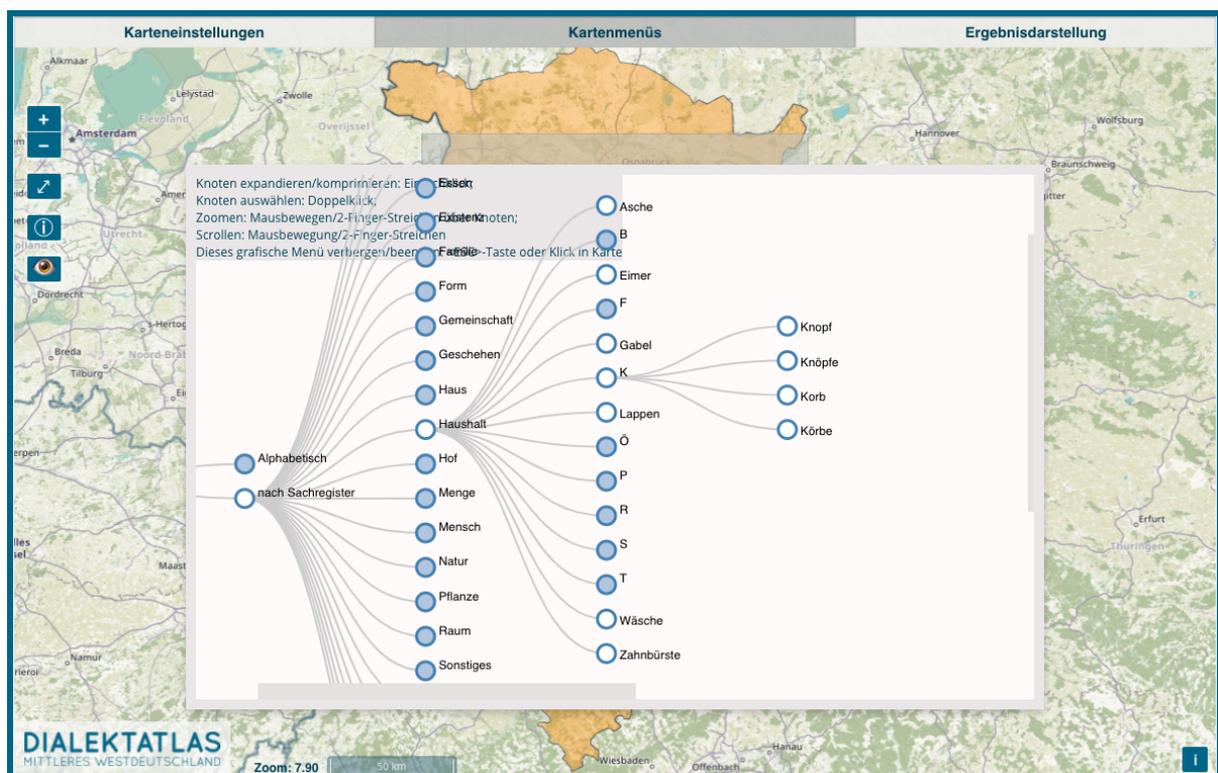


Figure 18: Graphical selection menu based on a D3-style hierarchy

Second, the *complexity* of the menus is simple by default, but changes on demand. For example, our basic query menu of word maps contains only three options (entering a word, selecting an ontological domain, and selecting from a word list). However, there is a check box allowing for the display of more options (selecting from a lemma list, choosing a part of speech (which will show pertinent suboptions), and choosing from a graphical menu). The Wenker menu simply lists all wenker sentences to choose from with check boxes, yet entering parts of words acts as a filter and immediately leads to a reduced check list. In general, menus of a certain type not only (dis)appear on mouse click, but also on certain mouseovers or keyboard entries, where appropriate. Correspondingly, users may develop their own preferences of how to interact with the system.

Third, we follow the principle of successive refinement of a query by offering ontological or linguistic categories to select from (in part, hierarchically). Technically, this is supported by automatically

restricting *all* options to the remaining compatible values after some selection (“self-restricting options”). To further improve performance, specifying a query is detached from database lookup, the latter being triggered only if some condition is met (for example, “only one item left in the list of available words” in a word map query). Query specification is therefore a light and quick process, which, with the possibility of undoing the last choice made (by clicking “letzte Auswahl zurücknehmen”), can be performed exploratively, too.

Fourth, *explorativity* is at the heart of the map interface (as has already been shown). For example, both the query selection and the granularity mechanism start with an overview; mouse over a POP field only shows the corresponding places (as a heat map) of that variant; detailed information about the data represented by a pie chart can be requested and is presented in a popup (percentage of the variant types at that location, with absolute numbers of places and persons); the relationship of similar pronunciation is made visible on reference point maps; setting a different background map or using a different kind of map is only one click away, and likewise –apart from the four data distribution display options–, zooming in or out in cluster maps instantaneously yields different perspectives on the data. A final aspect of comfortable explorativity is the use of comparison maps, where selected variants of possibly different words can be easily specified and explored.

There is a qualification regarding usability, however. Although our interaction scheme works well ergonomically, both with respect to content and query, it is far from being self-explanatory. Instead of abandoning our interaction principles, however, we simply decided to offer videos of the basic functionality at the entry to the map interface, and an elaborate help menu. This design choice for a steeper learning curve, but long-term interaction benefit, corresponds to a preference for multiple-time interested users of the map interface.

### 5.3 Technical aspects

The basic technical requirements of our map interface can be summarized as follows: to be able to automatically generate dynamic preview maps with state-of-the-art web software components; to have a responsive application, both with regard to query and presentation; and to have a persistent implementation to some extent.

We currently use a Parcel-bundled Open Layers 5.3.0 ES6-style Javascript application featuring JQuery(-UI) and D3 npm-organized modules<sup>17</sup> that accesses a MySQL database for text data, and provides links to the scientific cloud Sciebo for audio data. For tuning the selection, and presentation, of values from lists for certain input fields, we use the *awesomplete* autocompletion package by Lea Verou. The chores of linguistic data preparation for the query menu options (e.g., for hierarchical graphical menus like the one in Figure 18, but especially for the phenomena-related options of the expert version not described here) are performed separately with Node.js. As to map generation, we needed to use Voronoi cells of the explored places for our reference point maps (to provide for

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<sup>17</sup> Not loading such components via –potentially defunct– links to software sites guarantees availability of the used software components, and hence, some persistence of the map interface.

colourable areas). These cells (which are generated in QGIS® and imported as kml data) are also used to react tolerantly on place clicks in word maps. For fluid interaction, the map interface is heavily event-driven, minimizing clicking effort (for example, using mouseover for the initiation of some action, or automatically focusing on an input field if its parent is foregrounded). In addition to that, database calls are minimized, at least for the present map types.

## 6 Conclusion

Starting with an overview of the data and work flows, and of transcription, in the DMW project, this article described the algorithmic and technical aspects of the project's preview map generation. It was shown how the problem of massive dialect data variation can be solved by using a multi-level Soundex-like indexing scheme of the transcribed observants, ultimately achieving effective, digital, dynamic, interactive visualization. In the course of this, different aspects of preview maps were explained, and examples for their explorative use in what is called "Speaking DMW" or "Dynamic atlas maps of the DMW project" were presented.

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