Analyzing User Behavior with Matomo[1] in the Online Information System *Grammis*

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Abstract

The grammatical information system *grammis* combines descriptive texts on German grammar with dictionaries of specific word classes and grammatical terminology. In this paper, we describe the first attempts at analyzing user behavior for an online grammar of the German language and the implementation of an analysis and data extraction tool based on Matomo, a web analytics tool. We focus on the analysis of the keywords the users search for, either within *grammis* or via an external search platform like Google, and the analysis of the interaction between the text components within *grammis* and the integrated dictionaries. The overall results show that about 50% of the searches are for grammatical terms, and that the users shift from texts to dictionaries, mainly by using the integrated links to the dictionary of terminology within the texts. Based on these findings, we aim to improve *grammis* by extending its integrated dictionaries.

Keywords: user behavior, online information systems, automated tracking, Matomo, online grammars, online dictionaries, keyword analysis

1 Introduction

While much is known about the use of online dictionaries, only little is known about the use of complete online grammatical information systems such as *grammis*. *Grammis* is a grammatical online information system, hosted by the Institute for the German Language in Mannheim (Institut für Deutsche Sprache, IDS), that combines descriptive texts on German grammar with dictionaries on grammatical terminology and selected word classes (*grammis* 2018). It was created in the early 1990's as a research project that dealt with the complexity of writing grammars[2] and the challenges of transferring the linear structures of grammar books into hypertext formats. The CD-ROM-based version was changed to an online version in 2004 (Schneider & Schwinn 2014), and had its last redesign in 2017/18. The goal was to update the system technically in order to adopt the latest standards in web development, like the three-tier architecture including a MVC-PHP-Framework and mobile friendly design (Krasner & Pope 1988; Olanrewaju et. al. 2015). The restructuring and updating of the contents which started with the terminology on German grammar (Suchowolec et al. 2017) is still ongoing. The redesigned version of *grammis* went live on January 23rd 2018, while the old system will run in parallel until the final server shutdown in April 2018[3].

Today, *grammis* is structured into the three main parts: "Forschung" (Research); "Grundwissen" (Basic Knowledge); and "Ressourcen" (Resources), as shown in Figure 1.

1 The web tracking system Piwik was renamed Matomo on January 9th, 2018.

2 In this paper we use the term "grammar" in the sense of reference books of the grammar of a certain language, in this case German.

3 In the course of this paper we will refer to the old version of *grammis* as the "old *grammis*" and the new version as the "new *grammis*".

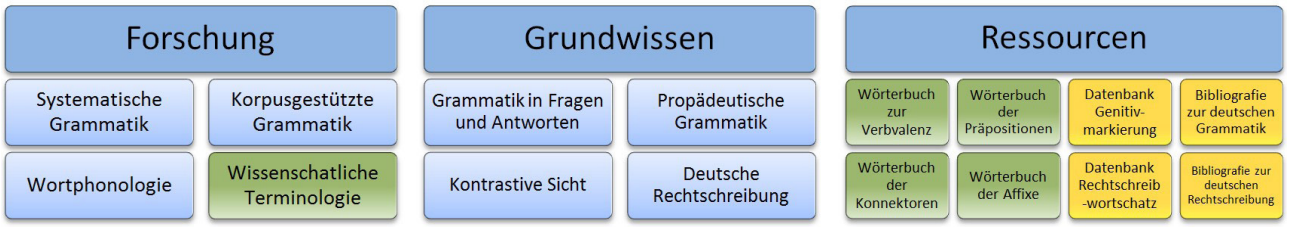

Figure 1: Main structure of *grammis* from the *grammis* homepage.

These tree main modules contain the components shown in Figure 2, where the light blue components are full text[4] components containing descriptive text passages on grammatical topics, the green ones are the dictionaries, and the yellow ones are research tools or bibliographies.

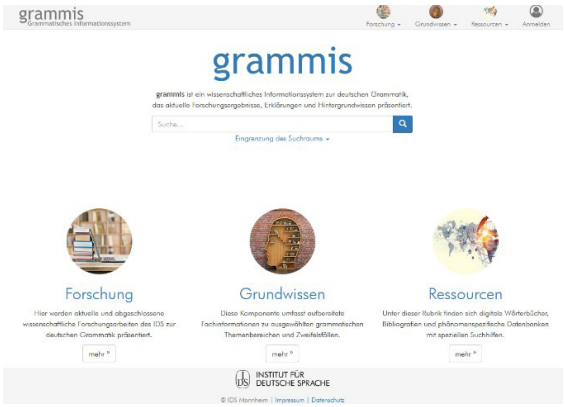

Figure 2: Components of the new *grammis*.

With the release of the new *grammis*, a new project focus lies on the evaluation of the system from the users' perspective. In order to make *grammis* more user-friendly, one aspect of restructuring and updating its contents is to take the actual users into account.

By doing so, we want to fulfil the demand for research on grammar use which has not yet been met, despite calls by Helbig (1992), Klein (2004) or Hennig (2010), in contrast to research on dictionary use, which has become a canonical research field in (online) lexicography (c.f. Müller-Spitzer 2014b; Tarp 2009). With regards to dictionaries, Lew (2015) states that the web has and will continue to bring out a great number of online dictionaries, which we believe is also true for online grammars. Besides *grammis* for the German language, other grammars like *canoo.net* (2018), or the recently provided "Variantengrammatik des Standarddeutschen" (Variation Grammar of Standard German, Dürscheid et al. 2018) are also available on the internet.

To begin with, we focus on the interaction between full texts and dictionaries within our online information system *grammis*, on the question of what exactly the users are searching for, and also look at the search results lists of the full text search feature. For that purpose we take a closer look at the four main dictionaries in *grammis*: the dictionary of the "Wissenschaftliche Terminologie" (Scientific Terminology), the "Wörterbuch der Präpositionen" (Dictionary of Prepositions), the "Wörterbuch der Konnektoren" (Dictionary of Connectors[5]) and the "Wörterbuch der Affixe" (Dictionary of Affixes).

4 We distinguish full texts from dictionary entries, whereas full texts mean descriptive text passages on German grammar.

5 In *grammis*, the class of connectors unites expressions that organize specific semantic relations between sentences. Traditionally, these include conjunctions, some adverbs and particles (*grammis* Konnektoren 2018).

Our interest lies in their interaction with the full text components describing the grammar of the German language. The three dictionaries on the word classes *prepositions*, *affixes* and *connectors* provide mainly grammatical information on the respective lemmas, like the position in a sentence, phrase structure, government, function and meaning. Access to the dictionaries is provided either through the separate dictionary components or via hyperlinks within the full texts on grammar. The latter are implemented as modal windows which open when the user clicks on a linked term. The terms within the dictionary components themselves can be accessed through either an alphabetical list or by typing a word into the search field.

For a quantitative overview of the content of *grammis*, Tables 1 and 2 show how many texts and entries per dictionary *grammis* has.

Table 1: Number of texts per component.

Component	Number of texts
Systematische Grammatik (Systematic Grammar)	928
Korpusgrammatik (Corpus Grammar)	136
Wortphonologie (Word Phonology)	11
Grammatik in Fragen und Antworten (Grammar in Questions and Answers)	223
Propädeutische Grammatik (Propaedeutic Grammar)	205
Kontrastive Grammatik (Contrastive Grammar)	867
Deutsche Rechtschreibung (German Orthography)	80
Total	**2,450**

Table 2: Number of entries per dictionary.

Component	Number of entries
Verbvalenz (Verbal valency)	677
Präpositionen (Prepositions)	132
Konnektoren (Connectors)	369
Affixe (Affixes)	285
Terminologie (Terminology)	388
Total	**1,851**

Since a lot of dictionary user research has been done (as stated above), we will take the results of previous studies within online dictionary user research into account, especially concerning the research methods.

2 Previous Research on (Dictionary) User Behavior

Research on grammar user behavior is still a desideratum in grammar writing. While the call for research on the user's perspective in grammar use came up in 1992 (c.f. Helbig 1992), the first attempts at investigating user needs and behavior concerning grammars of the German language were only recently made by Hennig and Lotzow (2016). Besides a questionnaire-based study (Hennig 2010) on the use of German grammars in general (What do you do when you have a question on grammar? Which grammar do you use and for what purpose? What do you expect of a grammar? etc.), Hennig (2010), Hennig and Löber (2010) and Hennig and Lotzow (2016) mainly investigated user behavior for the so-called *Duden-Grammatik* (Duden Grammar, Duden 2005; 2009), which is considered to be the most frequently used German grammar book in Germany (Hennig 2010: 20). These studies

were based on problem solving tasks and questionnaires with only a few subjects (n = 42 for Hennig & Löber (2010) and n = 6 for Hennig & Lotzow (2016)). As stated above, online lexicography has been taking the users' perspective into account for quite a long time (see short summary in Bergenholtz & Johnsen 2005: 118f.), which is why we want to draw on this research tradition. Bergenholtz and Johnsen (2005; 2007), for example, state that surveys based on questionnaires are problematic because they do not reflect the real user situation and are based on the users' memories of a rather artificially-constructed situation, and are sometimes even based on predictions of what the users think they might do in the future. Instead, they showed how log file analysis for dictionary research can be useful for gaining information about user behavior:

With a log file, you can track every single use of the dictionary, depending, of course, on the search possibilities. If it is only possible to search for the lemma, only data for the first access step in the dictionary will be available. Which lemmas have been looked up how often? Which lemmas have never been looked up at all? And which words have been used in the search field without result, i.e. how many and which lemma lacunas does the dictionary use indicate? (Bergenholtz & Johnsen 2005: 121)

Although this method has some limitations (e.g. the search possibilities mentioned above), it has the advantage that a huge amount of user data can be analyzed at once, unlike in user studies. Furthermore, Müller-Spitzer (2014a) states that using log files for the research into dictionary use is a "promising method" as it captures the usage in a real and authentic user situation. Previous research on dictionary use, however, teaches us to be careful with the interpretation of log file data, because the research process cannot be controlled, meaning that neither the background information on the users nor the contexts of the use or the success of a look up process can be determined exactly (Müller-Spitzer 2016; Lew 2011; Bergenholtz & Johnsen 2007). What the log files also cannot tell are the problems or the intentions the users might have had. Nevertheless, by using log file analysis, De Schryver and Joffe (2004) determined words that users searched for and that were not available in the dictionary. Subsequently, they added these missing lemmas to the dictionary, which resulted in an increase in the hit rate and certainly in greater satisfaction among the users.

Still, the use of server log files for the analysis of user behavior is problematic due to the fact that the server log files are in principle limited to what the server actually handles [..]. Only those activities of the user can be logged which are processed server-side, as opposed to those which are executed by the client (usually a web browser). Thus, the level of detail potentially included in log files is determined by the division of labor between server-side and clientside computing. Issues of data privacy can also be a limiting factor in log file analysis. (Lew 2015: 12)

Another way of collecting user data is to use web analytics systems, as was done, for example, by Lorentzen and Theilgaard (2012). They used Google's web analytics system, Google Analytics, to track the user behavior for the Danish online dictionary *ordnet.dk*, mainly to find out where their users came from (search engine, bookmarks, or from another website), and which lemmas they searched for that were not available in the dictionary. The results made it possible to improve the search process, e.g. the search for lemmas could be improved by adding further inflectional forms that could not be found before. They also combined the method with questionnaires, think-aloud-protocols and interview-based studies with selected users which additionally provided information on the users' backgrounds (intentions, satisfaction with the tool etc.). Tiberius and Niestad (2015) also used Google Analytics for the *Algemeen Nederlands Woordenboek* (ANW, Dictionary of Contemporary Dutch) to test the feature of presenting four different search possibilities to the users and the hypothesis that it would help them to better define what they are looking for, and that it would encourage them to use more than one search option. They stated that "Google Analytics is particularly useful for graphical overviews, for instance, of the types of visitors and the path most of them follow through the ANW application" (Tiberius & Niestad 2015: 29).

As using log files for the analysis of user behavior clearly has the same limitations for online grammars as for online dictionaries, we use the web tracking system Matomo (2017), which does not read the server log files, but tracks user behavior directly on the website, much like Google Analytics does in the studies mentioned above. Despite the stated disadvantages, we see a great potential in analyzing data that were created in real usage situations without overinterpreting the results. Therefore, we focus on what data can be collected with the web analytics system Matomo, and how we can make use of the collected data for the purpose of studying user behavior.

In our opinion, the biggest difference compared to dictionary research is that we cannot directly see if the users have found what they were looking for. In the case of lemma-based searches in dictionaries a log file or a web analytics system can reveal rather easily whether a searched word was found or is part of the dictionary at all. In conttrast, we assume that searches in a grammar are more complex in most cases, because they are very likely to aim for the explanation of grammatical concepts or the correct use of a grammatical form within a sentence or a text. This is why we expect the searches to consist of more than only one word, although we also expect single-word searches that might either be a lemma or a grammatical term. In the first case, we assume that the user is not searching for the meaning of the respective lemma, but rather for an explanation of its rules of inflection or function within a sentence or context. The search for terminology might be similar to the usage situation of a dictionary, because the user might look for a rather short explanation for the searched term in order to understand its concept. Nevertheless, with learning more about what kinds of search string the users enter, we hope to improve the search algorithm of the database and to obtain some insight into what we should present the users as a search result. As a start, we decided to focus on the integrated dictionaries in *grammis*. In the case of searches that do not refer to terminology, we need to develop a categorization system that defines the searches, by preference automatically, in order to quantify them.

3 Aims and Research Questions

Having updated the system technically, our current aims are to improve the grammatical information system *grammis* for the users, and to bring more users to our site. To begin with, we analyze the data collected by the web analytics system Matomo. Some general questions we want to answer as a first attempt to analyze user behavior in *grammis* are: How can Matomo be used in the analysis of user behavior? What data need to be tracked and can be tracked with Matomo? Who is using *grammis* when, where, how often, etc.?

In order to gain more information about the users' behavior with respect to the integrated dictionaries, we focus on the following three main research questions:

Research question 1: What do the users search for?
By answering this question, we want to gain information on the users' intentions and interests, especially with regards to the content of our dictionaries.

Research question 2: Do users use the integrated dictionary links by opening the modal windows when reading the full texts?
By answering this question, we want to find out if the integrated links are used at all, and what dictionary content needs improvement.

Research question 3: Which results (in the ranking of the results list) do the users select after a search?
By answering this question, we want to find out if the ranking of the search results for the full text search needs to be improved.

4 Matomo

Matomo is a web analytics platform to track Key Performance Indicators such as: visits, search keywords, site impressions etc. (Matomo 2017). Matomo in its basic configuration is free of charge, but some premium features are only available via a yearly subscription. The collected data are fully owned by the IDS and stored on a server which is located within the IDS network. This is in line with the high standards of the German and EU privacy policies, and the reason why we chose Matomo as a tracking system for our websites instead of Google Analytics, where the data will be stored on Google servers all over the world.

Matomo is implemented via a short JavaScript code snippet that is included in the head part of every web page (Matomo 2017). It is also possible to configure the tracking code to individualize which actions should be tracked. For example, we had to customize the script to track the use of the modal windows (see Section 6.2).

We included the premium feature *Search Engine Keywords Performance* to get all keywords from external search engines like Google, because these keywords will not be passed on from Google to Matomo (Matomo 2017) in the default configuration.

As to the visitors' actions, there is a difference between *hits* and *visits* (Matomo 2017). *Hits* are the number of page impressions, showing how often a page is requested in total. A *visit* is a stay on the website of one specific user. The user is anonymous, but recognizable to Matomo. During a visit a user will perform at least one single hit on one page. So, a hit is always a part of a visit, and a visit contains at least one hit. If the user is idle for more than 30 minutes, Matomo will count their next click as a new visit.

5 Basic User Statistics

In this section we give a short summary of the facts and figures of *grammis* during the period under examination. We collected the data between August 21st, 2017 and March 20th, 2018. This period we refer to as the overall period. With regards to the collected data for the search keywords, it was divided into four different periods (shown in Table 3). This is due to the fact that data for the new *grammis* could be collected only after its activation in January 2018 and that the external searches could be collected only after the implementation of the necessary Matomo feature added in February 2018 (see Section 4).

During the overall period we had a total of 478,914 visits, including 475,459 visits to the old *grammis* and 3,455 visits to the new *grammis*. During this time, we had a total of 871,291 hits (i.e. page impressions). This divides into 845,863 for the old *grammis* and 25,428 for the new *grammis*. The average visit lasted 1:36 minutes with 1.8 actions per visit of the old *grammis*, and 8:49 minutes with 8.5 actions per visit of the new *grammis*. The bounce rate (i.e. the rate at which users leave *grammis* after only visiting one page) was 79% for the old *grammis* versus 35% for the new *grammis*. Most visitors came from Germany (60%), followed by Italy (13%) and Spain (3.5%). Overall, the vast majority of visitors were from Europe (94.7%), with a few from Asia (2.7%), the Americas (2.1%), or from the African continent (0.4%).

Since the redesign, fewer visitors came via search engines. Instead, they found their way to the site directly (via bookmark or from other website links), which could be an explanation for the different bounce rate values. While many visitors of the old *grammis* came via Google just to visit one single page, the new *grammis* was (and still is) not ranked highly enough in the results list to get these

"one-click-visitors", which is why we suppose that at the moment we mostly have users who know *grammis* and use it regularly. With the final server shutdown in May 2018 (mentioned in Section 1), the old *grammis* will no longer be available, which is why we expect a better ranking in the Google search results which should lead to a rise in visitors and views. Additionally, we allowed Google to crawl our websites, a process that is not finished yet. With the completion of the Google crawl and the rising numbers of views we also expect a rise in user numbers due to a higher ranking in the Google results lists.

Looking at the internal searches in the overall period, we have 18,294 searches with 4,151 unique keywords in the old *grammis*, and 2,575 searches with 1,126 unique keywords in the new *grammis*. The keywords are case sensitive, so that the keywords "Verb" and "verb" are two unique keywords. For the actual numbers on the search data which was used in the keyword analysis, see Table 3.

6 Data Extraction and Analysis Tool

In order to make use of the data collected by Matomo to answer our research questions, we had to configure the data extraction and implement a unique data analysis tool into the admin backend of *grammis* (see Figure 3).

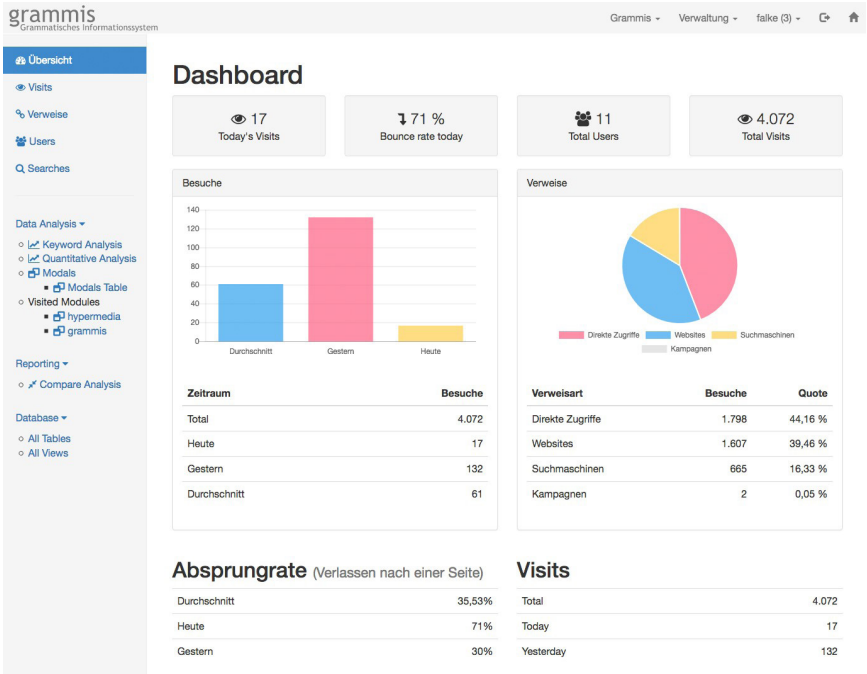

Figure 3: Data extraction and analysis tool.

The data extraction and analysis tool is written in PHP and included in our MVC-Framework. It retrieves the data from Matomo via their API, which can be called with an HTTP request including the query parameters (Matomo Tracking 2018). This makes it possible to retrieve the data for the period we want to look at and with several filter settings to retrieve only those datasets that are interesting for a given analysis. We included several charts and tables in our tool to look at the data from different points of view. Some charts and analyses made it necessary to process and convert the data from Matomo for our needs, so we implemented several methods to achieve this, e.g. for the extraction of the modals windows.

6.1 Tracking of the Keywords

The first research question (What do the users search for?) could not be answered with the standard configuration of Matomo, so we had to customize Matomo to make it possible to track the keywords[6] the users enter in both an external search engine like Google and in the *grammis* internal search field. To do this, we had to install the premium feature *Search Engine Keyword Performance* and connect it with the IDS Google Account (see Section 4), which was done on February 17th 2018. Since then, it has been possible to gain access to the keywords entered in Google[7]. We then extracted the keyword list, sorted by the number of hits for the old and new *grammis*, and combined the external list with the internal lists collected by Matomo. We thus had one big keyword list, including the external keywords for the old *grammis* and the new *grammis* and the two internal search keyword lists for both systems. We inserted the complete list into our database to analyze the data. The whole list consists of 6,040 data sets. The periods and number of total searches for each sub list are given in Table 3.

Table 3: Number of searches for different time periods and systems.

Platform	Type	From	To	Number of searches
old *grammis*	internal	2017/08/21	2018/03/09	4,069
	external	2018/02/17	2018/03/09	999
new *grammis*	internal	2018/01/23	2018/03/09	810
	external	2018/02/17	2018/03/09	162
Total				**6,040**

We then categorized the keywords the users were looking for to specify the type of the search. For this, we defined three categories: searches for terminology, searches for *object words*[8], and meta searches. Search strings of more than one word of which at least one was a grammatical term were counted as terminology searches, even if an object word was included. Meta searches feature keywords that consist, for example, of the name of a component or *grammis* itself, author names, etc.

For this purpose, we wrote a script that matched the keywords automatically with our integrated dictionaries to classify the keywords into terminological and object word searches. The categorization as meta search is done by hand (see two paragraphs below). With the matching, we additionally wanted to check the coverage of our dictionaries and therefore if the user is able to find what they are looking for at all, or if we have to add more terms and lemmas to the dictionaries.

When after that matching there were still keywords left which could not be found in our dictionaries, we checked these against external sources. First, we used the terminology list of *canoo.net* to find terms that are not part of our dictionary of terminology. When an object word keyword was not contained in our internal dictionaries we implemented an alignment with the DWDS by using their API (DWDS 2017) to get the word class for this keyword. Since we do not have a full word list within *grammis*, we cannot classify nouns and other word classes automatically.

Since there were still some keywords which could not be classified automatically, we exported the list to a Microsoft Excel document and categorized the unclassified keywords by hand. The categorization of the search strings that consisted of more than one word was challenging, especially when it

6 In this case *keyword* means the whole string a user is entering into the search field. The keyword can consist of a single word, multiple words or a whole phrase.

7 For all other search engines this is not necessary. Since to date the Matomo data show that almost no users come from search engines other than Google, this was a necessary configuration.

8 We use the term *object word* for all lemmas that are not terminology, which can be any words of a certain word class of which information is sought on. In a traditional sense the term *object language* defines what is the object of study in a certain language, while *metalanguage* defines talking about the objects of a certain language itself (Lehmann 2018).

came to interpreting the users' actual intentions. For example, the search string "*in oder auf*" ("in or on") – which turned out to be a very typical type of search – is classified as PREP, KONJ, PREP by our automatic alignment. Obviously, the user is not looking for all three word classes, but for the use of the prepositions alone, meaning that they aim to find the answer to an alternative question in which the user is looking for the correct preposition in a certain function or context. Since the classification of these object word searches consisting of more than one word is not trivial, and needs to be defined clearly, we did not include these for the analysis of the type of word classes that are searched for the most (see Section 7 and Table 5).

After the manual classification of the keywords, we had a list with two types of classifications: the type of request (terminological, object word, or meta search), and the classification of the specific word class of an object word (see Table 4). The statistics of this analysis are integrated into our admin backend of *grammis*.

6.2 Tracking of the Modal Windows

To answer research question 2 (Do users use the integrated dictionary links by opening the modal windows when reading the full texts?), we needed to take a look at the pages of the full text components the users visited and summed those up for each component of *grammis*. Therefore, we sorted the URLs in the hits tracker in Matomo and searched for the included component, since our URL structure is the domain followed by the name of the component, e.g. *https://grammis.ids-mannheim.de/systematische-grammatik*, where *https://grammis.ids-mannheim.de* is the domain, and *systematische-grammatik* is the component "Systematische Grammatik". A current text of this component is then browsed to via the ID of the database entry, which follows the component after a slash, e.g. *https://grammis.ids-mannheim.de/systematische-grammatik/244* to browse to entry 244 (in this case "Wortarten" (word classes)). With this, we can track and count each hit for every time a user directly navigates to a component, which can be through a link within *grammis*, a result page on an external search engine, or a bookmark.

To obtain more information about certain object words or terminology within the full texts, the texts contain links to the respective dictionary sources. These links open as modal windows, i.e. they open as a new layer on the current webpage, so that after closing the modal window the website is still open and the user does not need to click the browser's back button. Since the content of the modal window is loaded via an AJAX request, it is not counted as a hit by Matomo. Actually, in the default configuration an AJAX request is not tracked at all. To track the modal windows we had to adjust Matomo by including a few lines of JavaScript on every page to catch the event of opening a modal window. The script then sends the name of the modal window, its title, the URL of the current page the user is reading and the URL to the content which will be loaded and shown within the modal window to the Matomo database. Having done this, the use of the modal windows can be counted and the statistics were also integrated into our data extraction and analysis tool.

6.3 Tracking Behavior after a Search

Currently, the ranking of the search results in *grammis* is random due to the configurations of the database, which is why we want to analyze how the users interact with the results list in order to optimize the ranking of the results for the users. To answer research question 3 (Which results (in the ranking of the results list) do the users select after a search?), we planned to track the behavior of a user after a search. In the old *grammis*, the tracking of the links a user chose from the results page was not possible for Matomo due to several parameters which were sent with the results page and did not make it possible for Matomo to distinguish whether a link was a result or a search itself. With

this in mind, we configured the new *grammis* to track every internal search and the pages a user visits after a search. Still, the tracking of the chosen results causes some problems as it does not give us a complete tracking of the search-and-find process (in its standard configuration). It only tracks the keywords and the average number of hits of a page that has been chosen for a respective keyword, but it neither provides the exact pages that were chosen from the results list, nor the ranking number of the result in the list. Instead, Matomo tracks at which rate the user is leaving the page directly after the search without clicking on a result at all, and which pages exactly were clicked on after a search, but without providing the keyword that led to the result. So, for an evaluation of the result pages that are generated by our search algorithm from the database, we need to configure both the search algorithm and Matomo according to our needs and, furthermore, to combine it with a qualitative analysis of the users' decisions for certain results in the lists. Both could not be done within the timeframe for this paper but will be done in the future.

7 Results

Research question 1: What do the users search for?

Concerning research question 1, Table 3 shows that 80% of the search requests come from the internal search (4,879 of 6,040).

As can be seen in Table 4, the numbers for terminological searches (46.23%) and object word searches (52.88%) are almost equal, with a slightly higher number of object word searches. Looking at the overall hit rate, the numbers change (53.15 % for terminology and 44.37% for object words). This is caused by the lower number of terms in the dictionary compared to the number of entries for the dictionaries of the four word classes (see Table 1). This shows the high interest of the users in terminology and object words and, additionally, that the dictionary of terminology is highly requested. The number of meta requests is only 0.7% of all requests, but makes up 2.41% of the total clicks. Looking into the data, it became clear that users are using Google like a bookmark for entering the site, meaning that the users search for the word "grammis" in Google and come to the website via this link.

Table 4: Types of requests.

Type of request	Number of requests	Rate	Number of hits	Rate
(undefined)	10	0.17%	10	0.04%
object word	3,194	52.88%	10,584	44.37%
terminology	2,792	46.23%	12,688	53.19%
meta search	44	0.73%	574	2.41%
Total	**6,040**	**100.00%**	**23,856**	**100.00%**

As a next step, we took a closer look at the object word searches and what kinds of word classes were searched for. As stated in Section 6.1, we analyzed only the object word searches that consisted of one word due to the complexity of categorizing the multiple word keywords. Of course, we also looked at the length (in words) of the keywords. The most common search string consists of only one word (66%), while the longest string contains 27 words and basically represented a whole sentence. Taking this percentage into account, we covered and thus categorized at least more than half of the searches in *grammis* with this method. Another constraint for this analysis was that we only took those object words into account that referred to one word class alone. Obviously, many words can be defined as more than one word class due to the respective function or meaning in a certain sentence. Since this categorization is a rather complex task, too, we will do this as further research as well. Nevertheless,

for the analyzed part of the data, Table 5 shows that most users are looking for verbs (4,924 hits), followed by prepositions (1,325 hits), conjunctions (951 hits), and adverbs (837).

Table 5: Word classes of the object word searches.

Word class	Number of distinct searches	Hits
Verb	1,227	4,924
Preposition	260	1,325
Conjunction	184	951
Adverb	287	837
Noun	475	829
Pronoun	123	478
Adjective	174	344
Article	15	30
Total	**2,745**	**9,718**

The last step was the matching of the keywords with our integrated dictionaries and the external sources (as described in Section 6.1), on the one hand to have them categorized automatically, and on the other hand to see which words are available in our dictionaries. The results in Table 6 show that more than half of the searches (58.98%) could not be classified at all, and that only 7.1% of the requests were part of our dictionary of terminology, whereas 12.06% of the requests could be found in the terminology list of *canoo.net*. This might be due to the fact that the terminology of *grammis* for the most part contains highly scientific terminology[9] and *canoo.net* contains more traditional German grammar terms that are used in school, for example. The data show that the terminology searches often include said traditional terms, which is an important result for us when it comes to the expansion of our dictionary of terminology. Table 6 also shows that only 3.59% of the search requests could be found within the dictionary of prepositions, 0.05% within the dictionary of affixes, 5.21% within the dictionary of connectors, and 13.01% within the dictionary of verbal valency.

Table 6: Coverage of the keywords in the dictionaries.

Dictionary	Number of requests	Rate
not classifiable	2,367	58.98%
Wörterbuch der Präpositionen (Dictionary of prepositions)	144	3.59%
Wissenschaftliche Terminologie (*canoo.net*) (Scientific terminology *canoo.net*)	484	12.06%
Wörterbuch der Affixe (Dictionary of affixes)	2	0.05%
Wörterbuch der Konnektoren (Dictionary of connectors)	209	5.21%
Wissenschaftliche Terminologie (Scientific terminology)	285	7.10%
Wörterbuch zur Verbvalenz (Dictionary on verbal valency)	522	13.01%
Total	**4,013**	**100.00%**

Research question 2: Do users use the integrated dictionaries when reading the full texts?

To answer research question 2 we analyzed the use of the modal windows.[10] The results show that the option to open a modal window while reading a full text is used by only about 9% of the visitors (329

9 Since the main part of *grammis*, the "Systematische Grammatik" (Systematic Grammar) is based on the grammar book GDS (*Grammatik der deutschen Sprache* (Grammar of the German language) by Zifonun et al. 1997), the dictionary of terminology in *grammis* is also based on the grammatical terms used and developed in that grammar.

10 The duration for this analysis is from January 23rd to March 3rd, 2018, since these data could only be collected by Matomo after the update of *grammis*.

of 3,737 total visitors). Table 7 shows that, if a user is using a modal window at all, it is a grammatical term in almost 88% of the cases whereas the links to the different word class dictionaries are used only in about 12% of the cases.

Table 7: Use of the modal windows.

Modal windows	Number of visits with modal window interaction	Hits (site impressions)	Rate of hits
"Terminologie" (Terminology)	573	729	87.94%
"Grammatische Wörterbücher" (Dictionaries of word classes)	65	100	12.06%
Total	**638**	**829**	**100.00%**

Looking at the direct access rates to the components of *grammis*, we can see that the component "Systematische Grammatik" (Systematic Grammar) and the component "Wissenschaftliche Terminologie" (Scientific Terminology) have similar numbers of site impressions (3,265 vs. 3,142). The rate for all page impressions of these two components was 13.24% vs. 12.74% by which they have a higher ranking than the start page of *grammis* (2,616 impressions = 10.61%). The dictionary on verbal valency also ranks high with 2,201 impressions, while the dictionary of connectors has only half as many impressions (1,116). The two remaining dictionaries are ranked comparatively low with 207 hits for the dictionary of prepositions and 163 for the dictionary of affixes.

Research question 3: Which results (in the ranking of the results list) do the users select after a search?

As stated in Section 6.3, the analysis of the results after a search is still challenging. With Matomo in its default configuration, it is not possible to find out which position in the ranking of the results the user is selecting. Instead, it is only possible to capture that the user clicked on a link of the results list, without knowing which one it was exactly. To capture the position of that respective page, we have to configure Matomo in a way that is not trivial. Although it is possible to count the pages that have been chosen after a search, it is not possible to see what the users were searching for before they chose that exact page. The configuration of Matomo to track which keyword was searched for, which ranking position the chosen results page had, and which page exactly it was, will be done in the near future.

8 Conclusion and Outlook

The results for research question 1 show that the scope of our dictionaries is in need of improvement, especially the dictionary of terminology, as nearly half of the requests could not be matched with a dictionary directly. This includes multiple-word keywords in which none of the given words could be found. Nevertheless, the *grammis* search algorithm that is used on the website does always find results. This is due to the programming of the search algorithm on the database, which scans through all headlines and full texts of *grammis* and also looks for words with similar spelling, synonyms, etc., if there is no direct match with the given keyword. Still, this is not a satisfactory solution, because the users do not want random results for their search, but an answer to a specific question. The results also show that there is a high interest in terminology and object words. When it comes to object words, verbs, prepositions and conjunctions in particular are very often requested, which is why we will focus on improving those dictionaries in the future.

The results for research question 2 show that only a few users use the option of opening the modal windows while reading a full text, and that if they do they are mostly interested in the terminology links. The finding that the "Systematische Grammatik" (Systematic Grammar) and the dictionary of terminology are the most used components in *grammis* confirm that the terminology is a very important part of the system, and indicate that we should have a closer look at the interaction between these two components in future research.

Since research question 3 could not be answered due to the configuration of Matomo, we need to have a closer look into how we can collect the necessary data.

Overall, we can say that the use of Matomo, especially in combination with the configuration of our analysis tool, is very helpful in analyzing user behavior, in particular for single-word searches, while the categorization of multiple-word searches is much more complex and needs to be done manually.

For future research based on the detected user behavior, we plan to improve the search results by ranking the results in order of the users' preferences. Furthermore, the high bounce rate and high ranking of terminology and verbs suggest that many users only want to look up either a term or the spelling or inflection of a certain word. So, whenever a user is searching for a grammatical term or a word which is contained in our dictionaries, they will be provided with info boxes next to the results sets with detailed information on the specific term or word.

We also plan to analyze those searches that have been entered in search engines but did not lead to page impressions in *grammis*, thus gaining more users for our site. Nevertheless, we still have to decide how detailed the grammatical information in *grammis* should be, because we still aim to provide an academic version of our grammar that might not be useful for every type of user (e.g. students at elementary level).

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