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Setting trends with google: limits and perspectives when utilising search engine data

Steffen Springer[1] · Artur Strzelecki[2] · Branden Holmes[3] · Janine M. Ziermann-Canabarro[4] · Martin Kaatz[5] · Michael Zieger[1]

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Abstract

Search engine data, such as that provided by Google Trends, offers great research potential for many scientific fields. Google Trends analyses are already widely used to research and compare the popularity of search terms or topics through their relative search volumes. The present study identifies and discusses existing limitations of Google Trends data through illustrative examples, suggests possible solutions to these, and tries to broaden researcher perspectives of search engine data by demonstrating that there are numerous potential areas of application. The results show that, despite certain limitations, Google Trends provides a cost-effective and rapid way of sampling and analysing a very large database, which could benefit even more from improvements such as increased comparability. While being an important tool to document the origin and rise of new search topics and terms almost in real time.

Highlights

- Google Trends is a comprehensive data source with anonymous data from 2004 onwards, available since 2006
- Improving methodologies for utilising Google Trends data for scientific research
- Broadening researcher perspectives on the utility of Google Trends

Keywords Search engine data · Search terms · Search topics · Infodemiology · Relative data · Reliability · Standardization

✉ Michael Zieger
Michael_Zieger@icloud.com

[1] SRH Wald-Klinikum Gera GmbH, Gera, Germany

[2] Department of Informatics, University of Economics in Katowice, Katowice, Poland

[3] The Recently Extinct Plants and Animals Database, Two Rocks, Australia

[4] Department of Anatomy, Howard University College of Medicine, Washington, DC, USA

[5] DRK Krankenhaus Chemnitz-Rabenstein, Chemnitz, Germany

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1 Introduction

Analysing search engine data is an important research area with a variety of applications that is attracting increasing attention (Mavragani et al. 2018; Springer et al. 2021). There are several major Internet search engines across the world, varying in their geographical distribution, availability, and number of end users (Makhortykh et al. 2020; Yagci et al. 2022; Duka et al. 2023). These include, for example, Google, Bing, Baidu, DuckDuckGo, and Yandex (Shah and Ali 2023).

Google is currently the most popular search engine worldwide (Portier et al. 2020; Wijaya et al. 2021; Yagci et al. 2022; Lewandowski 2023), but new AI-based search engines are starting to emerge (Strzelecki 2024). Google Trends is a public web service that provides data to compare the relative popularity of different search terms (or topics) in the Google search engine (Springer et al. 2023). The analysis allows for both temporal and spatial resolutions from the year 2004 onwards (Proulx et al. 2014).

Google Trends offers a distinctive epistemological perspective on collective human behaviour by quantifying and visualising the search interests of end-users over time. It reflects the number of people which are curious at a given moment and in a specified geographical region (worldwide or regional), and what may engage or influence them. However, it is important to recognise that it does not explicitly reveal the underlying reasons or motivations for people's actions, which cannot be deduced from the data, but rather indicates that these actions are taking place (Springer et al. 2020a, 2025). Therefore, at best we can use inductive and abductive reasoning to infer the reasons or motivations for end-users to have engaged with the Google search engine in a particular way. While the idiosyncratic reasons/motivations of individuals are extremely difficult, if not impossible, to infer in the absence of specific knowledge about the identity of the individual(s). Nevertheless, positive causal links can often be identified when search volumes are significant enough to generate data and strongly coincide with real world events, such as press releases (Schubert et al. 2023), annual migration of animals (Kaatz et al. 2023), and annual commemorations (Zieger and Springer 2020; Zieger et al. 2023). Consequently, this knowledge about search behaviour provides insights into public awareness, cultural changes, and the emergence of new trends (Zieger and Springer et al. 2020; Van Huynh 2023; Vardi et al. 2021).

Google Trends analyses have already been used in a wide range of research areas (Springer et al. 2023). As a milestone for large data analyses, Eysenbach (2002) defined infodemiology, the epidemiology of (mis)information, as a type of research to study health information and misinformation (Eysenbach 2002; Strzelecki et al. 2023) and addressed the analysis of information, e.g. on the Internet, as a basis (Eysenbach 2009; Mavragani et al. 2018). This approach became an important tool, especially since the start of the COVID-19 pandemic (Eysenbach 2020).

The scientific area of health-related infodemiology encompasses a range of applications that are significant in the context of public health. The Google Trends platform enables the monitoring of the dynamics of the community's response to various epidemics or pandemics, including swine flu (caused by H1N1 virus), Ebola haemorrhagic fever (caused by Ebola virus), Zika (caused by Zika virus) and COVID-19 (caused by SARS-CoV-2) (Bobrowski et al. 2020). Applications also include the early detection of infections such as influenza or COVID-19 (Pervaiz et al. 2012; Olson et al. 2013; Porcu et al. 2023), as

well as the prediction of disease waves during the COVID-19 pandemic (Peng et al. 2020; Strzelecki 2020; Rabiolo et al. 2021; Saegner and Austys 2022).

Google Trends data can also be used for other topics such as: to improve forecasts for the housing or estate market (Dietzel 2016; Bulczak 2021); analysing trends in tourism (Cebrián and Domenech 2023; Menzel et al. 2023), the financial market (Preis et al. 2013; Ahmed et al. 2017; Huang et al. 2020), zoology (Kaatz et al. 2023), and nature conservation (Holmes et al. 2024), among others. Other applications of Google Trends data as a social data source include monitoring awareness of a variety of interests, such as extreme climate conditions (Kam et al. 2019).

In addition to the successful implementation and use of the Google Trends database for a wide variety of research tasks, the reliability of Google Trends analyses is also the subject of a growing number of studies (Nuti et al. 2014; Rovetta 2021; Eichenauer et al. 2022; Cebrián and Domenech 2023; Springer et al. 2023; Van Huynh 2023). Dietzel (2016), for example, discussed the use of subsamples by Google Trends and recommended that multiple queries be conducted at different time points and that the results be averaged to reduce sampling noise. Mavragani et al. (2018) reviewed the use of Google Trends data for research and established a framework for further analyses. Rovetta and Castaldo (2022) provided a proposal to enhance the precision of Google Trends for search terms with low volume. Springer et al. (2023) proposed a framework for further possibilities of standardization in relation to the maximum relative search volume that can be generated. Cebrián and Domenech (2023) discussed inconsistencies of Google Trends data. The authors highlighted that Google Trends data for queries with low search volumes can result in significantly deviating time series, necessitating a cautious approach to interpreting such findings. To address this issue, the authors proposed averaging multiple Google Trends data extractions to reduce potential bias (Cebrián and Domenech 2023). Rovetta (2024) also presented a recent paper on the reliability of the relative search volume and the regional online interest, and provided methodological advice on the correct collection of Google Trends data when using search topics and categories.

In summary, recent studies have demonstrated considerable promise in leveraging Google Trends data for a wide range of research domains, ranging from epidemiology and public health surveillance to market analysis and social science inquiries (Springer et al. 2020a, b; Kaatz et al. 2022; Strzelecki 2020; Menzel et al. 2023; Dietzel 2016; Meinzenbach et al. 2025; Springer et al. 2025). However, these studies also exposed significant methodological constraints, encompassing inquiries into data representativeness, temporal and spatial granularity, and the stability of relative search volume (Dietzel 2016; Eichenauer et al. 2022; Cebrián and Domenech 2023; Rovetta 2024).

Given the field's rapid expansion and the growing reliance on digital data for decision-making, a dedicated empirical assessment is essential (Jurić, 2021; Rovetta 2024). Therefore, research should identify the uncertainties inherent in Google Trends data, identify methods that increase reliability to establish best-practice protocols for data collection and interpretation. By addressing these research questions, researchers and practitioners will be better equipped to harness Google Trends as a cost-effective, real-time indicator -ultimately improving the validity of forecasting models, enhancing situational awareness in public health emergencies, and informing evidence-based policy interventions.

A main research question guiding the present study is whether Google Trends data can be considered reliable under various conditions. Therefore, the objectives of this study are to

discuss methodologies of data collection utilising Google Trends with illustrative examples, to address differences between search terms and search topics in Google Trends, to identify the limitations and perspectives of the methodology employed, to discuss the current options for standardization and comparability, and to demonstrate potential areas of application.

2 Methods

Google was selected as an example of a major search engine with worldwide importance. Google Trends (Google LLC, Mountain View, California, USA; https://trends.google.com/trends) is a web analytics tool that can be used to analyse search behaviour on the Google web service. The present study employed data from Google Trends to address the research questions.

The empirical study approach of this investigation is based on example-based research which, after defining the research question of whether Google Trends always provides reliable data, uses evidence from at least one counterexample as a method of falsification.

The examples of limitations were identified and documented based on the authors' experiences and observations in their previous work with Google Trends on a broad range of topics and methodologies in various areas, experimenting with different subject areas, and on the existing literature. Google Trends settings and parameters were carefully documented and varied as necessary to obtain meaningful examples.

The Fig. 1 delineates the conceptual map, which shows the different elements that make up the project. In Google Trends the following settings were used as indicated: region "worldwide" or "Germany", time range "2004—present" or "past 5 years", "all categories" or special categories, and "web search" were selected. Google Trends´ search terms or search topics were used as indicated.

Standardization is a key concept for increasing the comparability of research results. In their study, Springer et al. (2023) introduced the concept of "maximum generable interest" (MGI) as a universal reference point for analysing and comparing Google Trends data on different topics. During the global COVID-19 pandemic, there was unprecedented interest in the topic "Coronavirus" (Springer et al. 2023). The authors suggested using the peak search volume of this term in 2020 as a benchmark for future infodemiological and infoveillance research (Springer et al. 2023). A comparison of current Google Trends analyses without a joint reference is rendered challenging by the fact that Google Trends only provides relative and normalised data sets. By establishing MGI as a universal standard, Springer et al. (2023) aimed to enhance the comparability, interpretability, and methodological rigour of studies that use search engine data. Springer et al. (2023) also introduced graded search interest standards for search topics of medium and low interest.

When indicated, the universal standard topic "Coronavirus" for the maximum generable relative search interest for a health-related topic in Google Trends was used as described by Springer et al. (2023). Following Springer et al. (2023), the concept of "graded search interest standards" was implemented with topics "YouTube", "WhatsApp", and "Diabetes" as references. The conversion to the universal standard "Coronavirus" was conducted in a stepwise manner from a low to a high standard and the described conversion factor was employed for this purpose (Springer et al. 2023). This approach enables the straightforward alignment of an individual enquiry with the standard, thereby enhancing the accuracy of the

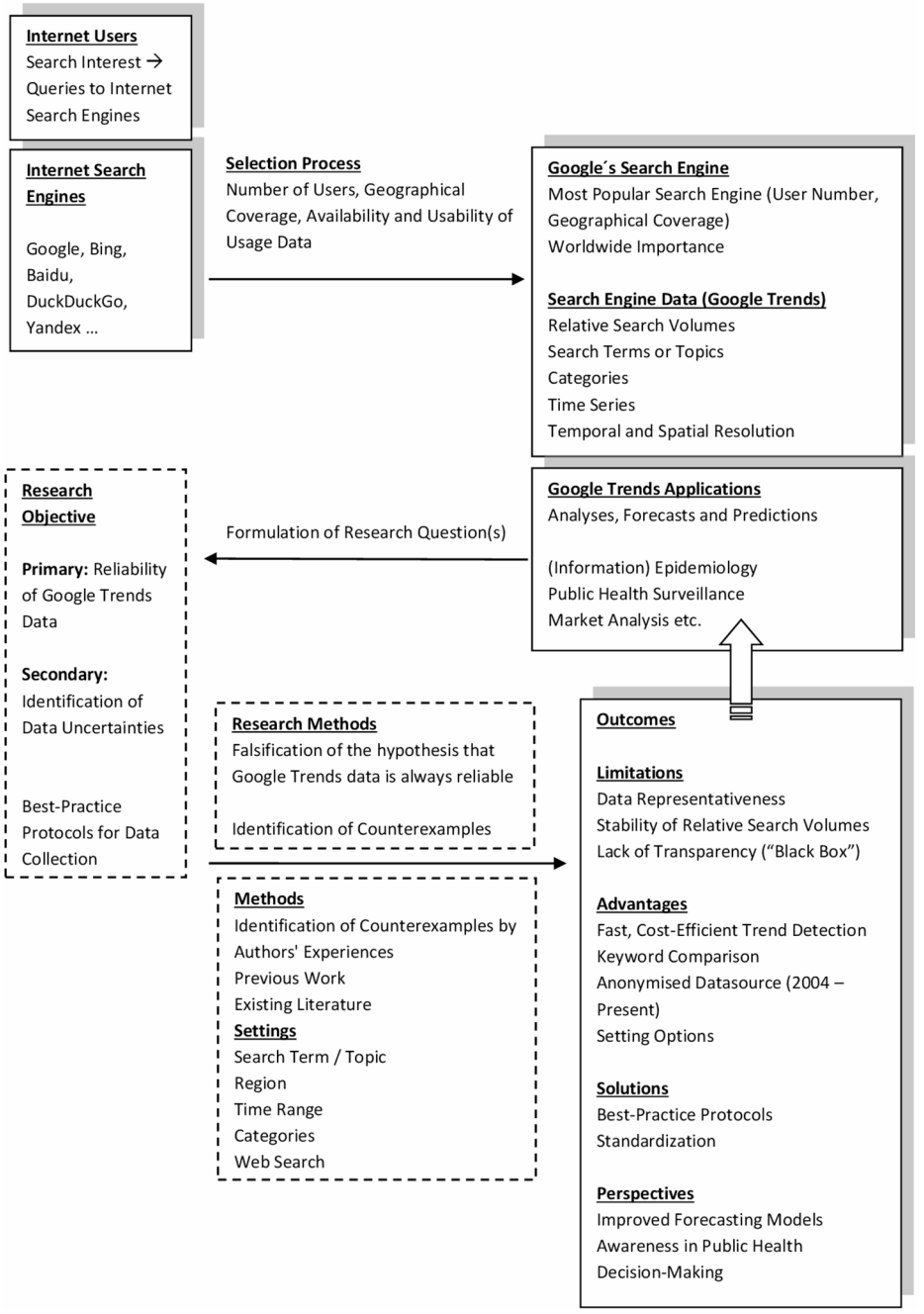

Fig. 1 Conceptual map of study scope

values. Data was accessed from April to June 2024, sometimes several times at different time points as indicated.

3 Results

3.1 Search terms and topics

Google Trends differentiates between “search terms” and “search topics”. For search terms Google Trends provides the relative search volume for that term. However, for search topics Google Trends provides the relative search volume for a thematic group of terms that share the same concept in any language (Holmes et al. 2022).

It has been observed that Google Trends occasionally offers several topics under the same name. The search topic “Allergic rhinitis” was found labelled as “Topic” and as “Disease” (Fig. 2A). But both Google Trends topics showed similar time courses, both worldwide and in Germany (Fig. 2B and data not shown). During the preparation of this study, it was observed that only one topic (“Topic”) was offered by Google Trends at a later date (data not shown).

Another example, the search term "organ donation", returned the following Google Trends topics: “Organ donation” and “organ donation” (Fig. 2C). In this case, it became evi-

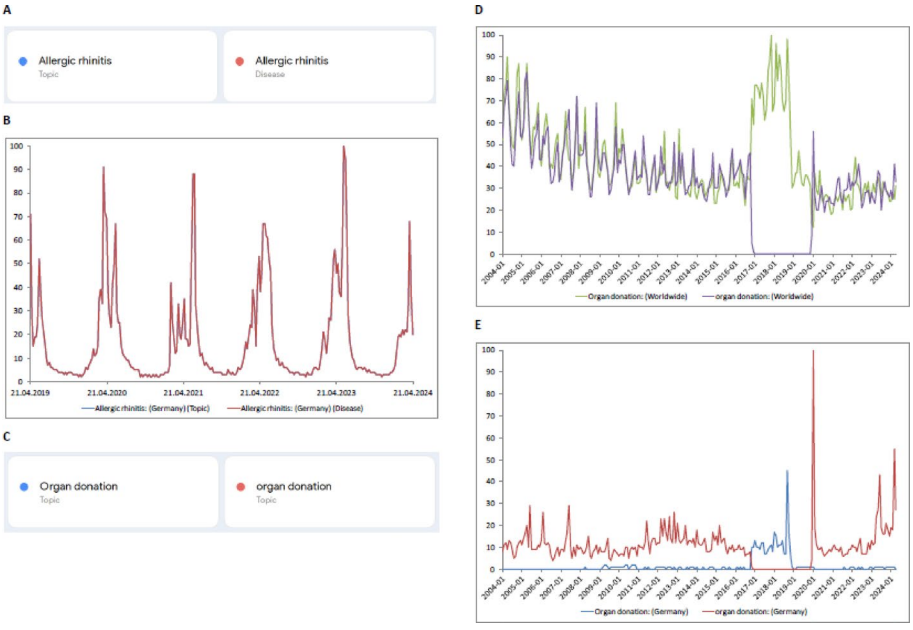

Fig. 2 Google Trends topics “Allergic rhinitis” (**A**, **B**), “Organ donation”, and “organ donation” (**C**) worldwide (**D**) and for Germany (**E**) (https://trends.google.com/trends)—The relative search interest over time for the specified topics (**B**, **D**, **E**) and screenshots (**A**, **B**) are shown. The examples demonstrate that Google Trends categorises topics with the same name (**A**, **B**) and comparable curves (**B**) differently (**A**). In contrast, other topics with identical names and grouping (**C**) show significantly different curves (**D**, **E**). Furthermore, in the case of “organ donation” there are notable shifts in the curves worldwide and for Germany at the end of 2016 (**D**, **E**)

dent that there were distinct curves for the worldwide and German contexts (Fig. 2D, 2E). The obvious difference in English was solely related to the uppercase or lowercase of the word "organ". For example, certain differences were also observed in the "Related queries" category of Google Trends results (data not shown), which may indicate that these topics were generated by Google Trends based on different search terms with different weightings. A similarly different behaviour of the curves was noticed in another example, "Indoor tanning"/"indoor tanning" (data not shown).

Furthermore, in the case of "organ donation" there were also notable shifts in the curves worldwide and for Germany at the end of 2016 that are difficult to explain (Fig. 2D, 2E). In addition, the example of the worldwide topic "organ donation" demonstrated that the search term "organ donation", which contributed significantly to the topic's search volume, did not exhibit such a sharp decline as the search topic "organ donation" (Fig. 2D) at the end of 2016 (data not shown). Consequently, the data sets for the topic may be unreliable during this period and should not be included in analyses.

Comparable shifts also occurred at the end of 2016 for the topics "Indoor tanning", "indoor tanning" (data not shown), and "Apple" ("Topic") (Fig. 3A). This may indicate a problem with the generation of Google Trends topics, particularly given that the timing of the improvements in the data collection system specified by Google Trends (worldwide and in Germany: from 1/1/16, 1/1/17, and 1/1/22 respectively) (Moon and Barlev 2024) does not align precisely with the observed shifts.

In addition, Google Trends search topics are supposed to cover the entire area. So, a search topic would be expected to have a higher relative search volume than a single search term unless it is obviously biased by the distribution of interest across different thematic areas, such as "Apple" (e.g., topic, fruit, technology company) (Fig. 3A) (Woloszko 2020). In another case, where it was not obvious that the term could have multiple meanings, a higher relative search volume was found for the term than for the topic (Fig. 3B). Also, it was noticed that "Apple" ("Topic") showed an unexpected drop in the relative search volume in the curve (Fig. 3A). Nevertheless, it was not possible to ascertain with certainty what this topic encompasses based on the designation as a "Topic", although the curve prior to 2016 (Fig. 3A) and the "Related queries" (data not shown) indicated a closer connection

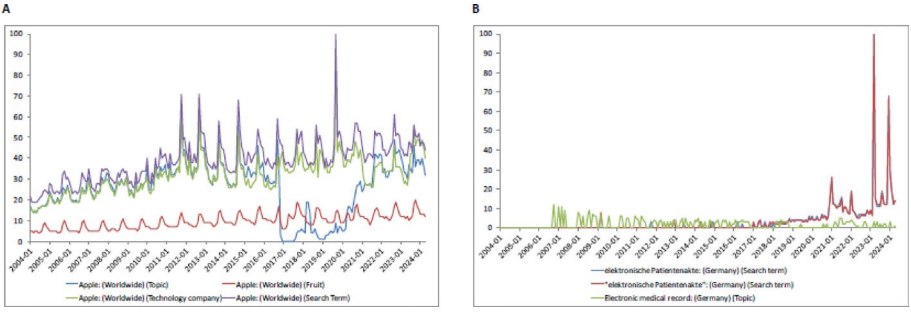

Fig. 3 Relative search interest: Google Trends topics and terms for "Apple" (**A**) and "elektronische Patientenakte" (**B**) (German for "electronic patient record"; Google Trends provided topic as "electronic medical record") worldwide and for Germany are shown as indicated (https://trends.google.com/trends). Search term "Apple" shows a high relative search volume in comparison with different thematic topics, such as "Apple" (e.g., topic, fruit, technology company) (**A**). In another case, where it is not obvious that the term could have multiple meanings, a higher relative search volume is shown for the term than for the topic (**B**)

with the topic “Technology company” than with the topic “Fruit”. The topic “Tennis” is another example where Google Trends offered several options. There were the search topics “Tennis” (“Topic”) and “Tennis” (“Sports”). While “Sports” seemed relatively clear, the generation of the more general “Topic” was less clear, especially considering that the relative search volume curves were very different (data not shown).

3.2 Categories

Van Huynh (2023) discussed the use of Google Trends categories in a nature conservation context and recommended using the parameter category with conscious intent. We found examples of curves for the topic “Corona” that did not appear very plausible. The topic “Coronavirus disease 2019” dominated in the “HEALTH” category (Fig. 4A). However, in the “Food & Drink” category, for example, the topic “Corona” (“Beer”) was unexpectedly not predominant (Fig. 4B). The exact generation of the unspecific topic “Corona” (“Topic”) also remained unclear (it appeared to have no connection with the disease). Consequently, Van Huynh’s (2023) statement that categories should be used with consciousness and caution remains valid.

3.3 Sampling noise

Sampling noise is a well-known artefact of subsampling (Steegmans 2021), and can lead to unjustified doubts as to the overall reliability of Google Trends when not appreciated (Franzén, 2023; Raubenheimer 2024). According to Dietzel (2016), it is appropriate to reduce the sampling noise through multiple queries. Subsampling from Google Trends could have a negative impact on the reliability of data collection, especially with low search volumes (Eichenauer et al. 2022). Although seasonal fluctuations were clearly evident in the case of “Allergic rhinitis”, the data from different query times exhibited deviations in the curves (Fig. 5).

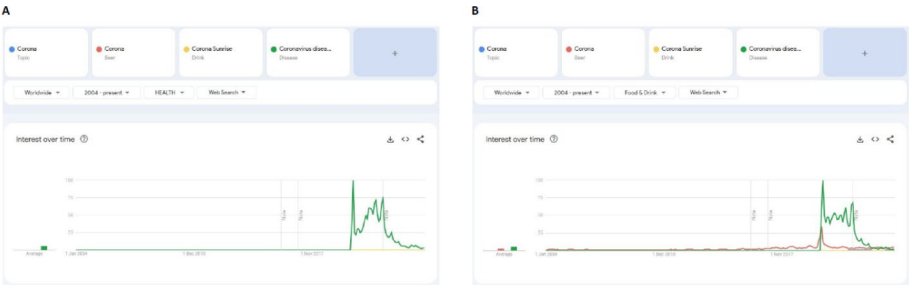

Fig. 4 Relative search interest: Google Trends examples for “Corona” topics worldwide with different category parameters: HEALTH (**A**), “Food & Drink” (**B**) are shown (Screenshots: https://trends.google.com/trends). The topic “Coronavirus disease 2019” dominated in the “HEALTH” category (**A**). The health-related topic “Coronavirus disease 2019” dominates not only in the “HEALTH” category (**A**) but also in the “Food & Drink” category (**B**) on the topic “Corona” (“Beer”)

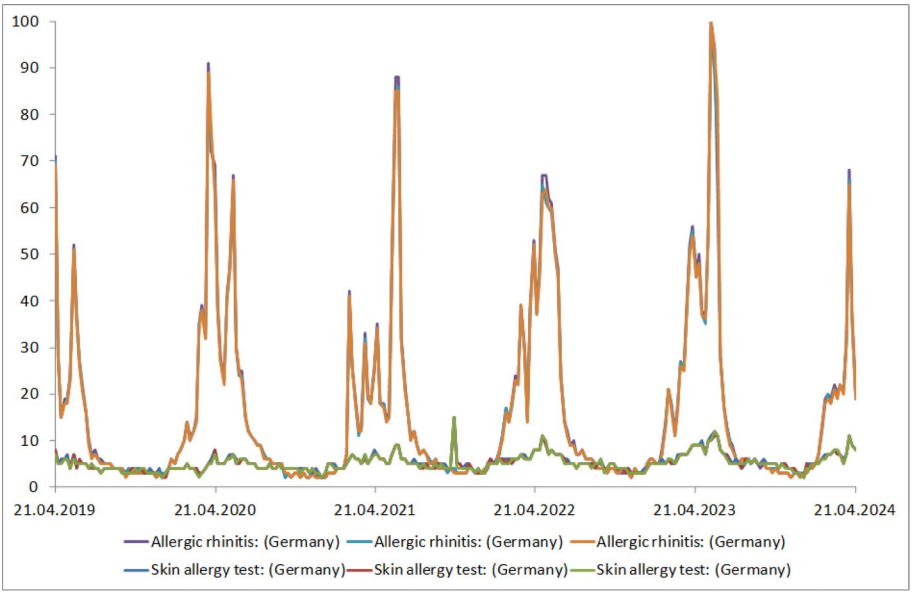

Fig. 5 Relative search interest: Google Trends data sampling noise for the past 5 years for topics as indicated for Germany (https://trends.google.com/trends; data accessed at multiple time points) are shown. Seasonal fluctuations are clearly evident in the case of "Allergic rhinitis", the data from different query times exhibited deviations in the curves

3.4 Modifications in data collection system

Google Trends announced from time to time a "Note" that "an improvement to our data collection system was applied" from 1/1/16, 1/1/17, and 1/1/22. However, the modifications or enhancements implemented have not been clearly documented by Google Trends, which raised questions about the reliability and comparability of data sets from before a modification with those after it (Hannen 2019; Myburgh 2022; Springer et al. 2023; Lolić et al. 2024). By extension, any data set that encompasses data from both before and after a modification may also be negatively affected. A study that focused on the 1/1/22 modification found that it produced 'measurement errors', sometimes displaying data for uncoined terms, or returning too few results (Liu 2024).

3.5 Relative search volumes, standardization, and time resolution

When investigating geographical distributions across national borders, as was necessary in the context of infodemiology or infoveillance, for example during the COVID-19 pandemic, it is important to consider not only the Internet usage of the population but also the varying popularity of different search engines in the individual regions or countries (Fig. 6), which would explain the lack of coverage in, for example, China, where the search engine Baidu is mostly used. Springer et al. (2023) also noted that the peak of worldwide search interest for the topic "Coronavirus" was higher than that for the topic "Coronavirus disease 2019" (COVID-19).

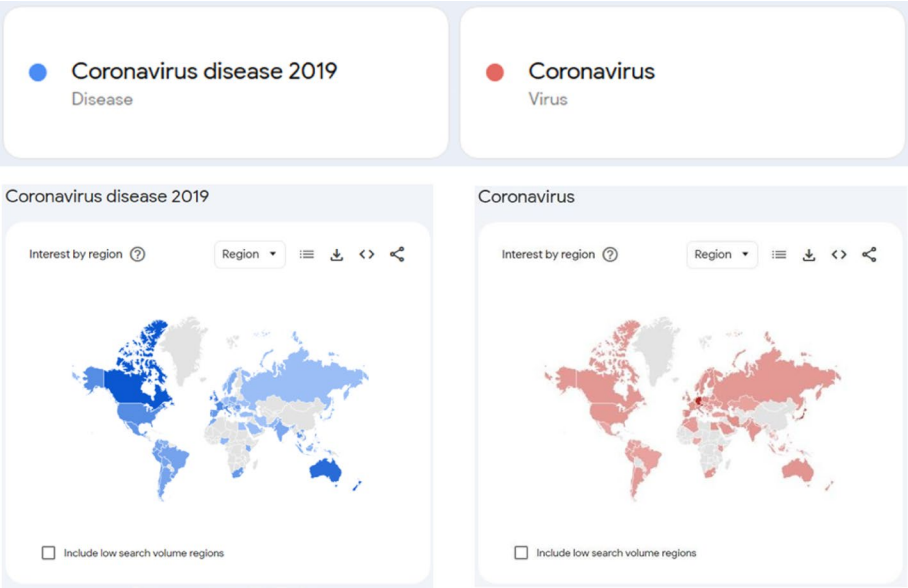

Fig. 6 Google Trends data worldwide for the past 5 years for topics are shown as indicated (Screenshots: https://trends.google.com/trends). A notable absence of coverage can be observed, for instance, in the case of China

Google Trends solved the problem of different search volumes in different regions and provides relative search volume data (Mavragani and Ochoa 2019). Google Trends provides only relative data and not absolute search volumes (Alibudbud 2023). Springer et al. (2023) have proposed a universal standard based on the maximum relative search volume that can be generated to improve comparability. In addition, graded standards can be used, similar to the standard ladders for DNA or protein sizes in gel electrophoresis (Ordovas 1998; Bubis 2021). As an example, the relative search interest for the topic "Allergic rhinitis" was converted to the universal (maximum) standard "Coronavirus" in an initial approximation by using graded search interest standards (Springer et al. 2023) (Fig. 7). Upon querying the topic "Allergic rhinitis" directly with the reference "Coronavirus" in Google Trends, the response was value < 1 (data not shown). However, with the graded standard method, it was possible to obtain more detailed values (Fig. 7).

Google Trends offers users the option of retrieving data in different time resolutions, depending on the time span in question. For example, results relating to longer periods of time are provided in a monthly resolution. Conversely, results relating to shorter periods are provided in a more detailed time resolution (Eichenauer et al. 2022).

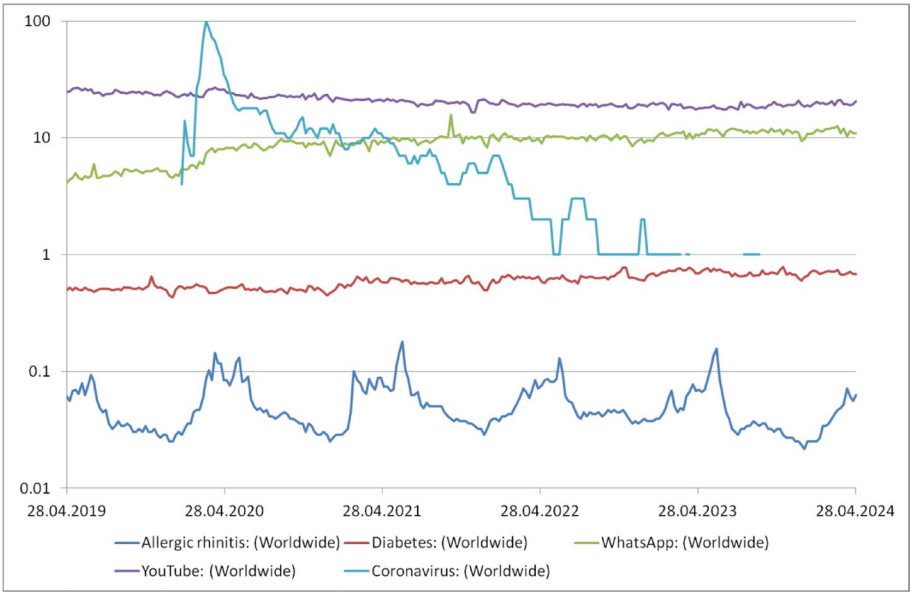

Fig. 7 Relative search interest: Google Trends data worldwide for the past 5 years for topics as indicated (https://trends.google.com/trends). According to Springer et al. (2023) the relative search volumes were c onverted to the universal standard "Coronavirus" by using graded search interest standards

4 Discussion

4.1 Limitations

Google Trends currently provides relative and not absolute data based on search queries made via Google's search engine. While this generates a valuable data source, it is subject to corresponding limitations. For example, the lack of information on absolute search volumes at different points in time makes it considerably more difficult to answer research questions relating to these volumes. Given the amount of search data available, it makes sense to analyse subsamples by Google Trends. However, this means that Google Trends data accessed by researchers at different times may differ.

In the currently free Google Trends web service, the use of search topics is particularly convenient and covers different languages, while search terms are easier and more concrete to define. One argument against the use of search terms is that only the specific term in the corresponding single language can be analysed. This can be very biased if there are multiple meanings (e.g., "Apple": fruit, company, etc.).

Although the use of search topics is recommended in accordance with the better coverage of a thematic area, it should be used with caution due to the not very transparent generation by the Google Trends service. As the example of "organ donation" shows (Fig. 2D, E), it can lead to very contradictory results that are not easy to explain. Due to the abrupt changes in the curves (Fig. 2D, E and 3A), there is the possibility of a "bug" in the service by Google Trends when generating the topics. It was also observed that one search topic used at the start of this project (Fig. 2A, B) was no longer offered by Google Trends, specifically "Aller-

gic rhinitis" ("Disease"). This indicates a limited potential for the reliability and possibility to reproduce data sets.

The classification and assignment of search topics is also not always as clear as in the case of "Apple" (Woloszko 2020). There is certainly still potential for optimization here. Google Trends' approach of enabling users to combine topics with categories represents an intriguing opportunity to refine the definition of search topics. However, this approach is not yet wholly effective in all cases and, as Van Huynh (2023) noted, the use of categories should be approached with awareness and caution. In an approach based on illustrative examples, our results also support Rovetta's (2024) conclusions, e.g., with regard to the use of search topics in Google Trends, where care should be taken to ensure that these include meaningful and thematically appropriate search terms or, if necessary, to switch to well-defined terms as an alternative. Furthermore, the data corroborate Rovetta's (2024) recommendation that caution should be exercised when utilising categories.

Additionally, while it is beneficial that Google Trends announces improvements or changes in the data collection system or the geographical assignment (Moon & Barlev 2024), they are mostly not well documented leading to justified doubts about the reliability of data sets for queries at different points in time (Hannen 2019; Myburgh 2022; Springer et al. 2023; Liu 2024; Lolić et al. 2024). This is only semi-transparent, because the specifics and methodology of the changes are not entirely clear. Consequently, Google Trends remains a somewhat opaque entity—a "black box"—for researchers in many respects. Therefore, further research is necessary to try to tease out the precise effects and consequences of the modifications, since Google is not likely to be forthcoming with this information given its confidential nature, and the fact that they still have not released the details of the first modification to their data collection system. Rovetta (2024) also highlights potential implications of the Google Trends improvements and makes the plausible suggestion that it should be checked whether certain events related to the research question are possibly dated to the time of the Google Trends improvements, and thereby potentially lead to erroneous conclusions. It is also difficult to determine the search intention behind a Google user's search query (Zieger and Springer 2020). Even for technical search topics and terms, where the user base is the most likely to be limited to professionals and students, search intentions can still be broad, for example, training, education, research, development, but also purchase interest, application, pure interest in technology, etc.

As demonstrated by Schubert et al. (2023), Google Trends can be influenced by press releases, which act as a significant trigger of interest. This phenomenon can be employed to track the impact of publications but must also be considered when analysing Google Trends data (Schubert et al. 2023). It is likewise important to consider the rapid and widespread dissemination of information, which can be a mixture of facts, speculation, untruths and lies in the form of deceptions, fabrications, falsification, etc. This phenomenon, which has been termed "infodemic", must be considered, when evaluating Google Trends results (Strzelecki et al. 2023).

Google Trends offers temporal resolutions according to the length of the time interval analysed (Cebrián and Domenech 2024). For larger time windows, only a monthly resolution is available. This can make it challenging to detect both short-term and low-volume changes (Eichenauer et al. 2022). Eichenauer et al. (2022) also described frequency inconsistencies between daily, weekly, and monthly data sets.

The differences in general Internet coverage and popularity of the Google search engine in the individual regions or countries, for which data are available, also leads to limitations in the validity of Google Trends analyses, which may only refer to Internet users and specifically to the part of the population that uses the Google search engine.

4.2 Solutions

As with all scientific research, the need for transparency is an important key aspect in the generation, evaluation and use of research results as a basis for further scientific research and development (Campbell et al. 2014; Valdez et al. 2020). A more transparent presentation of the generation of search topics, the presentation of implemented improvements, and the absolute search volume by the Google Trends service would therefore be highly desirable. Absolute data offers a more comprehensive insight than relative data. Google Trends, however, provides relative rather than absolute data, which may restrict the potential for identifying search volume developments over time and for comparing countries (Sousa-Pinto et al. 2020). One option is a tool that provides absolute data, namely *Google's Keyword Planner* (Sivesind et al. 2021; Zitting et al. 2021). Google's Keyword Planner is a tool that identifies the most relevant keywords and estimates the search volume. However, despite its popularity, there is a lack of transparency regarding the exact procedure that Google uses to generate these estimates (Zink et al. 2019). The Google Keyword Planner tool provides information on keywords, with historical data available for up to four years and data granularity of one month. This means that it provides information only on the number of searches within an entire month. Additional parameters for processing searches in Keyword Planner include geographic selection, allowing choices between specific countries or the entire world, and language selection, specifying the language in which the query is searched. An additional feature beyond what Google Trends offers is the breakdown of the average monthly search volume into mobile devices (i.e., smartphones) and overall data. However, since the mobile device market dominates search results, the overall data graph effectively mirrors the smartphone data. It should also be noted that this is a commercial tool accessible to subscribers of Google's advertising service.

It is challenging to ascertain the search motivations of users when utilising the Google search engine. Accordingly, a research approach that employs *appropriate combinations of search terms* was employed with the objective of enhancing the classification and comprehension of search motivations (Springer et al. 2025).

The proposed *standardization* using, for example, a maximum generable relative search interest or universal standard can help to better compare different research studies in the future (Springer et al. 2023; Cebrián and Domenech 2024). In addition, the application of graded standards will also enable more precise value determinations without neglecting comparability. However, without further effort, the very small values, for example in the course of the universal standard ("Coronavirus") themselves remain less precisely determinable. These would have to be determined separately at certain time intervals. Rovetta and Castaldo (2022) have proposed a corresponding procedure that provides for a combination of different curve sections to improve Google Trends accuracy.

Google Trends enables users to query long-term data sets for the relative search volume from 2004 onwards. However, for data sets spanning a longer period, such as from 2004 to the present, the time resolution is limited to a monthly frequency. Conversely, for shorter

Table 1 Practical solutions for users to improve the use of Google Trends

Limitations	Solutions	References
Relative data (relative search volume)	Tool that provides absolute search volume (Google's Keyword Planner)	Schultheiß et al. (2023) Zink et al. (2019)
Lack of transparency in generation/coverage of search topics and utilizing of categories	Ensure that the topic includes meaningful and thematically appropriate search terms ("Related queries") Switch to well-defined terms as an alternative Caution should be exercised when utilising categories	Rovetta (2024) Van Huynh (2023)
Comparability	Use of standardization protocols	Springer et al. (2023) Cebrián and Domenech (2024)
Sampling noise	Use of standard protocols to obtain multiple queries at different time points Averaging to reduce the sampling noise	Dietzel (2016)
Time resolution for long time intervals	"Multi-chained windows" (MCW) method	Rovetta and Castaldo (2023)
Search motivations of Internet users	Appropriate combinations of search terms	Springer et al. (2025)

time frames, a more precise time resolution is possible. Rovetta and Castaldo (2023) suggested the use of a method known as *"multi-chained windows" (MCW)*, which describes a combination of high-resolution data sets along the time axis. For their MCW method, the authors combined shorter periods, i.e., they were putting together intervals with higher resolution to "obtain high-resolution search volumes in long time windows" (Rovetta and Castaldo 2023).

While the responsibility for the transparency of data generation or modifications lies with the Google Trends provider and can only be demanded by researchers, there are certain practical solutions that researchers can utilise to enhance the quality and comparability of their analyses. Table 1 provides a concise overview of some important key points.

4.3 Chances and perspectives

Google Trends provides researchers with the opportunity to access and analyse data in a cost-effective and timely manner, offering regional to global insights (Ziehfreund et al. 2022). Google Trends provides access to a vast repository of anonymised data. In the context of the information age, where data mining is on the rise, data protection must also be considered. In this regard, Google Trends data offers a highly effective anonymisation option due to the vast quantity of data available.

Google Trend was launched in 2006 and is now almost 20 years old (Jun et al. 2018). Google Trends provides data from 2004 onwards its temporal dimension is growing every

day (Jun et al. 2018). The availability and intuitive analysability of the data also opens interesting possibilities in the field of citizen science, where citizens contribute to scientific knowledge (Bonney et al. 2016; Haklay et al. 2021). The participation of citizen scientists is guaranteed by the use of the readily available database. Furthermore, information entry via Google is generated by a large number of citizens through their enquiries, as demonstrated by the example of bird migration (Kaatz et al. 2023).

Since August 2024, Google has provided a user-friendly interface for the trending topics of the last seven days in its 'Trending now' section (Schwartz 2024; Worzel 2024). This allows users to obtain data including details such as search volume (Schwartz 2024; Worzel 2024). This can be viewed as an illustration of Google's efforts to enhance the usability of its services, while also underscoring the necessity for researchers to expect changes. These alterations may enhance and supplement the usability of data generation, while other modifications beyond the direct influence of researchers may also impact the database, consequently affecting their research. Google Trends is not only a valuable tool for research in infodemiology sensu stricto (i.e., health related) but even for more, broader, and future applications, e.g., finance, markets, medicine, biology, nature conservation, energy or climate change, etc. (Hassani and Silva 2016; Hoffmann et al. 2023). The utilisation of specific categories, individual time spans, and the geographic distribution affords further options for the refinement of the analysis, thereby enabling the identification of seasonal and geographic distribution patterns (Kaatz et al. 2023). Building on the framework of diverse publications by various authors, Google Trends will in perspective continue to provide a versatile tool for medicine, economics, biology, nature conservation, and much more, opening further applications for answering a wide range of research questions. Wherever and whenever end user engagement with the Google search engine can aid research, Google Trends will be a useful tool. Provided that the researcher engages in best practice by using standard operating procedures where they have been established, and otherwise responsibly collecting and analysing the data given its relative nature.

At a higher level, the data set generated via Google Trends can then be compared with those from other digital corpora to determine if there are any meaningful similarities or differences in the trends they display (Correia et al. 2021). For example, a study of Israeli Internet users found marked differences in search interest for native plants between Google Trends and Wikipedia (Vardi et al. 2021). This potential for differential trends across multiple digital corpora means that multiple culturomics sources should be sampled whenever a multi-source data set will be more accurate for the purposes of the study.

In this qualitative research, limitations of Google Trends as a research tool has been demonstrated. Therefore, further research should focus on a systematic study of the frequency of the limitations found and their statistical evaluation in order to quantitatively evaluate the reliability of Google Trends data. With further knowledge of the degree of reliability of the data, the existing framework for utilising this data can be further refined. The proven breadth of possible applications merits further investigation of the data quality provided and should be placed on a solid scientific basis in this respect. In order to ensure the quality and comparability of future research, it is essential to establish methodological standards with regard to data collection, analysis and interpretation.

The utilisation of Google Trends as a research instrument gives also rise to a number of ethical challenges that must be given due consideration. Despite the fact that the web service provides aggregated, anonymised search volumes, it is important to note that users

may not always be aware that their search queries are included in public data sets. However, anonymising the data sets is crucial in protecting users' personal rights and contributing to the generation of new scientific knowledge, at least in the context of scientific data use.

However, it is essential to consider the unequal distribution of internet access and digital skills, as this can lead to a distortion of the data and limit the generalisability of the results. The opacity of Google's algorithms also poses challenges to the principles of reproducibility and validity, as researchers are unable to comprehensively assess the transformation of raw search query data and the potential occurrence of algorithmic biases. Search trends, which are susceptible to distortion by opaque algorithms and influenced by certain events and media reports, should not be accepted uncritically as a basis for reactions by public health systems or governmental policy. It is imperative to undertake a thorough examination and validation of the results with independent (real-world) data.

5 Conclusions

The reliability of a given Google Trends result can be enhanced by conducting multiple queries over an extended period of time and then averaging the results (Dietzel 2016). In addition to enhancing its reliability, the utilisation of standards and the endeavours to enhance the resolution of Google Trends data will facilitate the optimisation of its utilisation for scientific enquiries (Rovetta and Castaldo 2023; Springer et al. 2023). In the case of questionable topic generation by Google Trends, recourse to search terms can be recommended, e.g., if only one language is relevant for the analysed region and one main topic is relevant (Rovetta 2024). Nevertheless, it is important to consider the potential alternative meanings or uses of the terms in question, such as the cases of "Apple" or "Lion" (Woloszko 2020; Holmes et al. 2022; Moon and Barlev 2024). Furthermore, when utilising categories, it is imperative to exercise caution and care (Van Huynh 2023; Rovetta 2024). The use of standards for search volumes facilitates comparability of relative Google Trends data with other research work (Springer et al. 2023). Building on the framework, Google Trends is already a versatile tool that will undoubtedly continue to contribute to the answering of a wide variety of research questions.

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