

#Covid-19: An Exploratory Investigation of Hashtag Usage on Twitter

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Abstract

Background: The literature highlights Twitter as a vital instrument tool for health policy-makers for health communication and promotion. Furthermore, Twitter is a tool allowing us to understand the focus of people regarding a topic of interest.

Objective: To explore the hashtag usage about Covid-19, identifying hashtag frequencies and themes.

Method: A total of 28.5M tweets have been retrieved, of which 6.9M tweets included hashtags. The data was analyzed using data science and natural language processing libraries. Qualitative analysis was performed using thematic analysis.

Results: Demographic analysis showed that only a few users contribute with more than ten tweets (77.5k of 3.36M). 907k different hashtags were used. Of these, only 1192 hashtags were used more than 1000 times. The qualitative analysis resulted in 13 themes. The top three themes regarding the number of hashtags used were related to Covid-19, identifying information, interventions, and geographical tagging.

Conclusions: The results provide first insights for policy-makers and health practitioners to identify relevant tweets and to choose appropriate hashtags for health communication. They also show the potential for health policy-makers to contribute more to the Twitter activity.

Keywords: Covid-19, Hashtags, Twitter

1. Introduction

Covid-19 keeps the world in suspense. However, little is known about what people and organizations are dealing with concerning this pandemic, the issues that affect them, and the fears that accompany it. In recent years, social media have become a way to share information quickly and thus provide a variety of information about private, business, and political events. Bal et al. [1] highlighted the amount and significance of the information communicated on social media regarding Covid-19, such as Twitter. Twitter is also an instrument for health communication and promotion [2]. Furthermore, twitter may be used to disseminate information of essential developments rapidly (e.g., described by Nesbitt et al. [3] for Multiple Sclerosis). Most health policy-makers have Twitter accounts, though their activity level varies [4]. Alrazaq et al. [5] call for the “*need for stronger and more proactive public health presence on social media*”. When communicating on Twitter, framing is important (cf. Bal et al. [1]), as the terms used (e.g., lockdown) create different associations. Kreuter and Skinner [6] also highlight that it is crucial to adjust the message given to the audience, which requires them to understand the motivations, and how messages are used and read. For health policy-makers to be successful in their usage of Twitter, they need to use a strategic approach [7]. Hence, to understand the stakeholders and how certain aspects of topics are framed, we

conducted an exploratory study of themes derived from Twitter hashtag usage regarding the Covid-19 pandemic as input for strategy definition.

Regarding Covid-19 discussions on Twitter, Park et al. [8] looked at news-sharing and analyzed networks of Twitter users to understand how news information has spread in networks. Odlum et al. [9] investigated topics discussed in the African American community, investigated through topic modeling. They identified four themes, namely: 1) symptom and transmission patterns, 2) treatments, prophylaxis, and cures, 3) effectiveness and impact of interventions by institutions, 4) fear – protect and help the African American community. Kouzy et al. [10] raise the concern of misinformation on Twitter, finding that 24.8% of the Tweets contained misinformation. They also highlighted that public health accounts were the most reliable, highlighting the importance of their presence on social media.

This paper aims to explore the themes people are talking about on Twitter about Covid-19 based on hashtags. Hashtags are used by users to indicate the topic of a particular Tweet. The aim is achieved by answering the following research questions:

- *RQ1: How frequently hashtags are used?* This research question determines the usage of hashtags concerning quantitative measures (number of tweets with hashtags over time, the frequency distribution of hashtags).
- *RQ2: What are people talking about on Twitter?* This re-

search question identifies themes by looking at the hashtags. Hashtags are used by Twitter users to provide a “heading” for their tweets, indicating what tweet is about according to the user.

By answering the research questions, our study complements existing studies by investigating hashtags. PubMed and Scopus did not reveal any study with this focus. Furthermore, a large corpus of Tweets (6.9M) and hashtags were utilized in the investigation. The research may benefit health policy-makers in their health communication due to the awareness of specific hashtags used to communicate in different themes. Furthermore, the framing used and the prevalence of topics in society can be used for reflection.

2. Materials and Methods

2.1. Data collection

Chen et al. [11] searched Twitter for Covid-19 related tweets and provided the Tweet-IDs. Details on the search procedures are provided in Chen et al. We used the Tweet-IDs to obtain the Tweets of April. Our data was collected during the first half of May. The tweet data was obtained using Hydrator (<https://github.com/DocNow/hydrator>). In total 28.5M tweets were captured. Only tweets with hashtags were selected, and the tweets were filtered for relevant information (demographic information such as geolocation, user identifiers and names, and hashtags). After that, 6.9M tweets remained for analysis.

2.2. Data analysis

For the analysis, the Python programming language was used. Descriptive statistics were created using the Pandas library [12]. The pre-processing of the textual strings of hashtags was done using the spaCy library [13] for natural language processing. In order to identify the themes, we used thematic analysis [14]. Themes emerged by reviewing hashtags sequentially and continuously comparing and refining codes. One code emerged (“Non-English/ ambiguous), which comprised of hashtags that were non-English or used abbreviations or terms with various meanings. Before hashtags were assigned to the category, they were searched for and checked in Google and Tagdef (<https://tagdef.com>).

2.3. Threats to Validity

Tweets were identified through a keyword search by Chen et al. [11], and keywords were added over time. We acknowledge that there exists a possible bias due to the search. Also, the period (April) provides a snapshot. Further hashtags are likely to be added, and their priorities change over time.

Only a subset of the Tweets was coded using thematic analysis. We acknowledge that this may lead to bias—the hashtags used for the analysis cover 56% of all hashtag-usages in Tweets. Thus, the effect of the threat is likely to be small.

We also acknowledge that the identification of themes is subjective, as the coders may be biased (e.g., through media and

news consumption about Covid-19). For traceability purposes, all hashtags and their assignment to themes are documented in the supplementary material.

3. Results

3.1. Demographics

Concerning demographics, we analyzed the origins of the hashtags for countries and looked at the distribution of tweets about users.

Geographical distribution: Figure 1 shows how tweets were geographically distributed. The number of tweets was log-transformed, as due to a few countries having a very high number of Tweets, differences would not be visible for lower numbers. A small portion of the Tweets was geotagged (92.7k), which is less than 1%. Twitter-users have to opt-in for Twitter to use geotagging. Half of the geotagged tweets come from four countries, namely the US (63.6k), India (12.6k), Great Britain (9.4k), and Indonesia (4.7k). As a country playing a major role in the discussion during the time, China is only represented by 272 tweets.

Users: We also investigated the activity of users on Twitter, looking at how many tweets can be attributed to individual users. In total 3.36M users tweeted. Of these users, the clear majority only tweeted once (2.3M). Only very few users tweeted more frequently. 77.5k users produced ten and more tweets, 100 and more by 851 users, and 1k and more by nine users. This confirms previous research in which the uneven distribution of tweets across users has already been shown [15]. Putting the numbers from the perspective of health organizations, the World Health Organization (@WHO) tweeted 94 times, and with this is ranked 970 among the users. The Centers for Disease Control and Prevention (CDC) did not have tweets, as they established an account in May (@CDCGov).

3.2. RQ1: How frequently hashtags are used?

The total number of tweets with hashtags is 6.9M of 28.5M tweets collected. As shown in the figure, the increase in tweets was constant for the investigated period.

In total, 907K unique hashtags were used. The distribution of the number of times unique hashtags were used is highly skewed, which is shown in Table 1. Of all unique hashtags 60 % were only used once. Only around 9 % of the hashtags were used more than ten times. The frequency analysis provides input to the analysis of the themes, which are identified during thematic analysis. The total number of hashtag usages was 145.3M. Only looking at the number of usages of hashtags that were used more than 1000 times, they already cover 82.1M usages, which is more than half of the total usages. In other words, 0.001% of all unique hashtags represent 56% of all hashtag-usages.

3.3. RQ2: What are people talking about on Twitter?

We first provide an analysis of themes and, after that, present a detailed analysis of each theme.

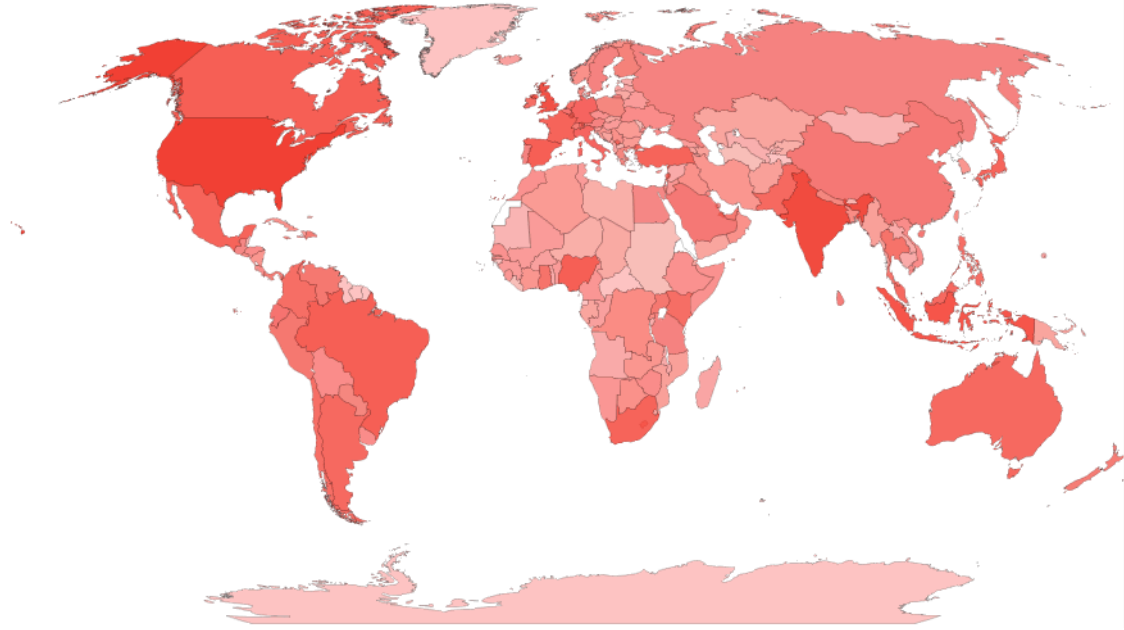


Figure 1: Number of tweets (log-10) in relation to geographical location (darker colours indicate a higher number of tweets)

Table 1: Frequency of Usage of Unique Hashtags

Times used	No. hashtags	No. hashtags (%)
Count > 1M	2	0.0002
100K <= Count < 1M	8	0.0008
10K <= Count < 100K	59	0.0065
1K <= Count < 10K	1123	0.1238
100 <= Count < 1K	10772	1.1872
10 <= Count < 100	69844	7.6973
2 <= Count < 10	272731	30.0570
Count = 1	552840	60.9271
	907379	100.0000

Themes: Given that the majority of hashtags are only used seldom, we focused on the most frequently used hashtag. We started the hashtags used 1000 or more times (1190 hashtags as indicated in Table 1). As pointed out by Morse [16], saturation is a good indicator of when to stop coding. Already looking at the first 40 hashtags, the majority of themes were identified. Thus, this provides confidence in the completeness of the results with regard to the themes when reviewing the first 1190 hashtags. With the analysis, we covered 82.1M hashtag-usages in tweets.

In total, we identified 13 themes. We first define the themes and, after that, show the hashtags representing each theme. A complete overview of the top 15 hashtags in the themes is shown in Figure 3. A full list with hashtags and frequencies can be found in the supplementary material.

1. **Covid-19 identifying:** These hashtags indicate that the tweet is related to Covid-19.
2. **Interventions:** Hashtags indicate measures to combat the epidemic.

3. **Geographical:** Hashtags provide a geographical reference.
4. **News and media:** Hashtags indicate that new information is available, identify the tweet as news, or refer to concrete news platforms and personalities.
5. **Health:** Hashtags refer to the health of individuals or groups, or healthcare institutions or medicine.
6. **Social:** Hashtags refer to social interaction, activities, and life in the context of Covid-19.
7. **Political:** Hashtags refer to politicians and their actions, or politicized topics, which are not directly related to Covid-19. We also included hashtags that provide a political value on an aspect of Covid-19 (e.g., lockdowns).
8. **Event:** These hashtags point to specific points in time (e.g., April 1st) or particular events (e.g., Wimbledon).
9. **Business:** Hashtags reference topics related to business and economy, or to companies.
10. **Religious:** Hashtags refer to religious figures or practices.
11. **Technology:** Hashtags refer to different types of technologies.
12. **Law and order:** Hashtags to executive powers (e.g. police), legal aspects, or crimes
13. **Military:** Hashtags explicitly reference the military or roles within.

Each of the themes emerged from several hashtags. Figure 2 shows the number of occurrences of hashtags for each theme. We briefly discuss the hashtags for the themes. The most frequent theme is related to hashtags identifying tweets as Covid-19, with over 3.5M occurrences, followed by measures

taken, geographical and news, and media. In the discussion of the themes, we show the top 15 hashtags. In the complementary material [17], the full list and frequencies are documented.

We discuss the individual themes in the order of the frequencies of the hashtags related to them.

Covid-19 identifying: Three hashtags stand out as identifiers for Covid-19 (see Figure 3(a)), namely #covid19 (over 3M usages), #coronavirus (over 1M usages) and #covid (over 500k usages). This information is particularly useful when searching Twitter for Covid-related information.

Interventions: A variety of measures taken have been discussed in the Twitter community (see Figure 3(b)). The clear majority of hashtags refer to social distancing (#stayathome, over 400k usages) and related terms by which the distancing is achieved, such as lock-downs, staying at home, and quarantine. The hashtags also cover other measures recommended by health practitioners, such as hygiene-related (e.g., #washyourhands, #disinfectant, and #handwashing), or the usage of masks (e.g., #mask or #ppe, which stands for personal protective equipment).

Geographical: An overview of the hashtags for geographical locations are shown in Figure 3(c). Note that hashtags referring to the same geographical location have been combined, and the counts have been added. A wide range of geographical locations has been mentioned. China, India, Wuhan (the city the virus originated from), the USA, and Europe are the most frequently mentioned, which may be attributed to their size (see demographic information in Section 3.1). However, specific cities are high up (10th most frequently mentioned location with hashtags #newyork, #ny, etc.) in the ranking, particularly New York City, which was the first major hotspot in the USA.

News and media: Figure 3(d) shows media-related hashtags. Various terms were used to identify that the hashtag was about news, such as #breaking and #breakingnews. Furthermore, hashtags refer to specific news channels (e.g. #foxnews or #cnn) or social media types (e.g. #facebook and #twitter). One particular media event was highlighted, which was the press conferences of US-president Trump (#trumpsspressbriefing, #trumpsspressconference). The hashtags also highlighted concern about

media, fake news. The hashtag #fakenews referenced these. We also find hashtags related to art and artists.

Health: Hashtags related to health refer to safety (e.g., #be-safe, #stayhealthy, and #staysafe), see Figure 3(e). They reference the epidemiological goal of stopping the exponential growth of infections (#flattenthecurve). Furthermore, references to medication were made (e.g., #hydroxychloroquine, #vaccine, #chloroquine, and #remdesivir). Health practitioners are acknowledged for their work (e.g., #healthcareheroes, #healthcareworkers, and #clapforcarers). Various medical conditions are also discussed in relation to Covid-19, namely Ebola, Malaria, Cancer, Autism, and HIV.

Social: The life situation under lockdown is referenced as #quarantinelifelife and is the by far most frequently mentioned hashtag in the category (see Figure 3(f)). Hashtags highlight positive wishes and encouragement (e.g., #staystrong, #inthis-together, #staypositive), prompting help and sticking together (e.g., #help_them and #unity). Hashtags also point to concerns, such as #isolation and #confinement. Furthermore, a new term (#covidiot) was introduced, which refers to persons who act irresponsibly in the pandemic context.

Political: A range of politicians are referenced by hashtags (Figure 3(g)), the most frequently mentioned being Donald Trump (31k times), followed by Emmanuel Macron (13k times). Further politicians mentioned (e.g., Boris Johnson, Angela Merkel, and Xi Jinping). A set of hashtags calls for specific demands on politics, such as #firefauci (referencing the director of the CDC, Anthony Fauci), #chinamustpay, #chinamust-explain, or #makechinapay. Most of the hashtags calling for actions are hence directed towards China. Furthermore, hashtags are used to evaluate politicians and their actions (e.g., #chinaliedpeopledied, #trumpliesamericansdie, and #trumpmeltdown). To indicate that politics in the context of a specific country are discussed, people use the country code in combination with pol, e.g., #cndpol, or #auspol.

Event: In the context of events (Figure 3(h)), a range of challenges have been formulated, such as #darkselfiechallenge, #jo1challenge, or #dontrushchallenge. On April, 7, the world health day is among the most frequently mentioned event hashtags (#worldhealthday, 12.3k times). Daily motivations can be

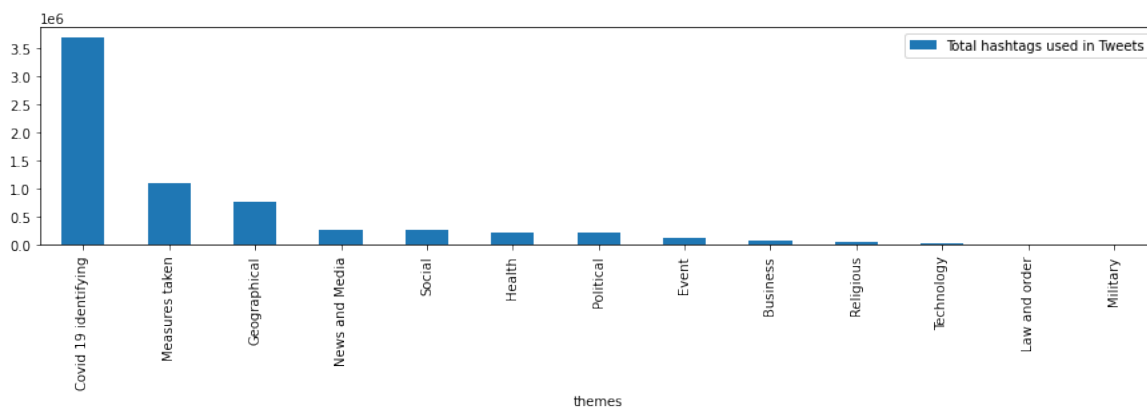
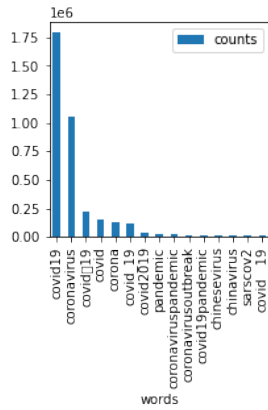
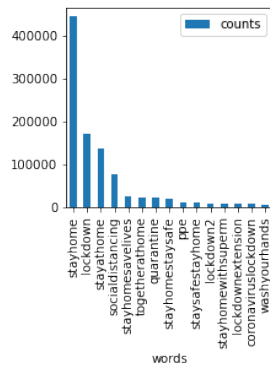


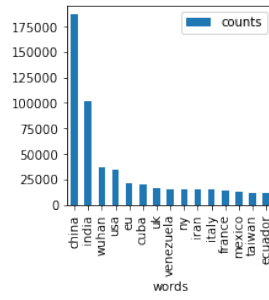
Figure 2: Total number of tweet occurrences for themes



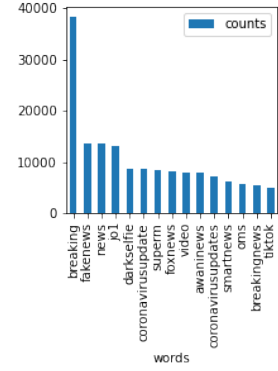
(a) Theme: Covid-19 identifying



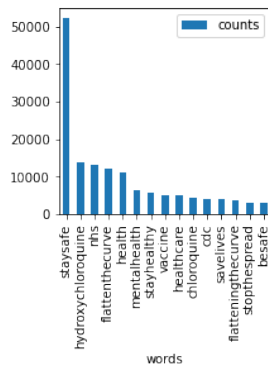
(b) Theme: Interventions



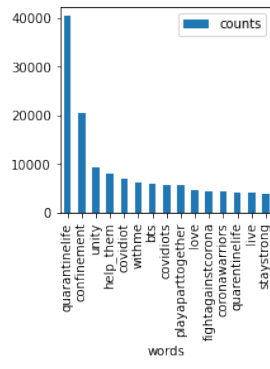
(c) Theme: Geographical



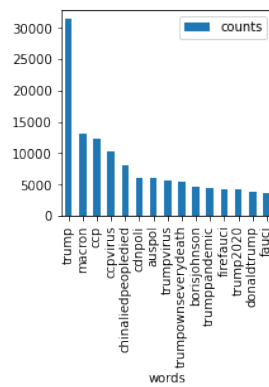
(d) Theme: News and media



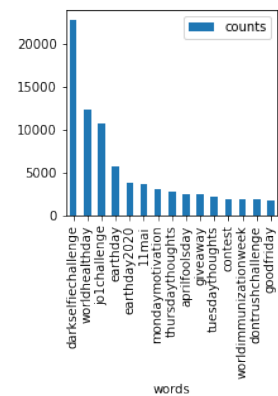
(e) Theme: Health



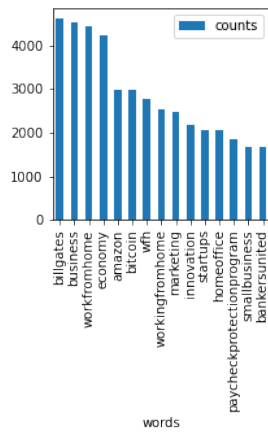
(f) Theme: Social



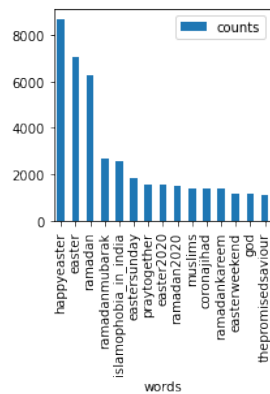
(g) Theme: Political



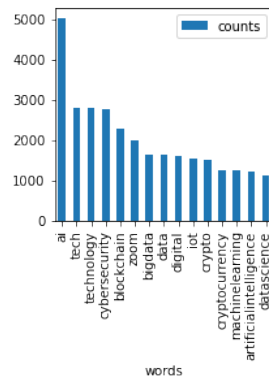
(h) Theme: Event



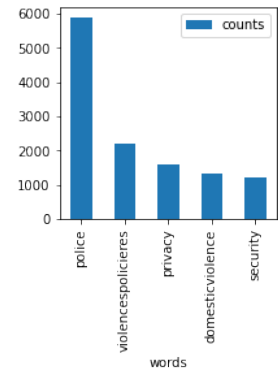
(i) Theme: Business



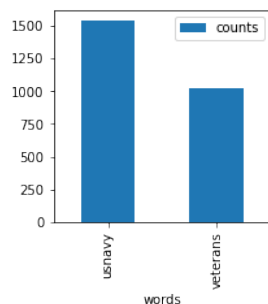
(j) Theme: Religious



(k) Theme: Technology



(l) Theme: Law and order



(m) Theme: Military

Figure 3: Hashtags and frequencies in themes (top 15)

found under hashtags such as #thursdaymotivation, or #saturdaymotivation. Similarly, thoughts of the day are referred to as, for example, #wednesdaythoughts, #saturdaythoughts. We also find media events, such as streaming house music online and partying during the lockdown (#lockdownhouseparty).

Business: Business-related hashtags (Figure 3(i)) use the hashtags #business or #economy as an identifiers. The most frequently mentioned business personality is Bill Gates (#billgates, 4.6k mentions). One major concern during the pandemic was working from home, which was indicated by various hashtags (#workfromhome, #workingfromhome, #homeoffice). One specific corporation was mentioned frequently, namely Amazon (#amazon).

Religious: Major religious celebrations, Ramadan and Easter, are taking place in April, and hence are frequently referenced (see Figure 3(j)). A religious concern (islamophobia) was highlighted (#islamophobia.in.india). The fight against Corona was coined using the religious term jihad (#coronajihad). General identifiers for religion are made by mentioning particular religions, groups of people, or god (see, e.g., #islam, #muslim, and #god, respectively).

Technology: Various technologies are mentioned (Figure 3(k)). The most frequent mention is artificial intelligence (#ai) and related terms (e.g., #bigdata, #data, #machinelearning, and #datascience). Zoom (#zoom) as a tool for video conferencing, often used to arrange meetings from the home office, is also frequently mentioned. Further examples of mentioned technologies are topics related to blockchain (#blockchain, cryptocurrency) and security (#cybersecurity, #crypto).

Law and order: The most frequently mentioned hashtag in this category refers to the executive power (#police); see Figure 3(l). Concerning police, police violence is highlighted as a concern (#violencepolicieres). Furthermore, legal matters such as privacy (#privacy), security (#security), and domestic violence (#demesticviolance) were mentioned.

Military: In the military category (Figure 3(m)), only two hashtags were found, namely Us Navy (#usnavy) as a military organization and the reference to veterans (#veterans).

4. Discussion

We first discuss the implications for practice, followed by implications for researchers.

Implications for practice: Hashtags are a means for identifying Tweets. Searching for them allows us to find information for further detailed analysis. By analyzing the themes and hashtags, health practitioners know the sets of hashtags associated with specific themes, which can be used to search for Tweets. Furthermore, in order to find tweets by health practitioners and policy-makers, it may be important to choose the right hashtags. As an example, when tweeting for a specific theme and topic (e.g., health), we suggest using frequently used Covid-19 identifying hashtags (see Figure 3(a)) in combination with hashtags relevant for the specific theme (see Figure 3).

We also would like to highlight the potential for a higher activity rate on Twitter by public health organizations. Looking at the data for April, public health organizations could be

among the top 100 users of more than 3.36M tweeting users when publishing ten tweets per day.

Health policy-makers and practitioners may benefit from monitoring trends on Twitter, which may help identify dominant topics of interest, which may inform policy-making. As an example, we understand how framing takes place or may get an indication of issues and problems highlighted frequently in the broader community. One concrete example is the different types of framing taking place (e.g., #lockdown versus #stayathome, where #stayathome is more positive).

In the technology category, various terms concerning data science are mentioned in the context of Covid-19. Hence, this may indicate that people seem to recognize that they play a role in the pandemic. Our study of hashtags is one example of how data science can help in understanding what is happening in the community regarding the pandemic. Note that we used existing libraries for the analysis, which could “out-of-the-box” be widely used to build tools for policy-makers. We encourage investment in interactive tool development to monitor the situation on Social networks continuously.

Our study presented a global analysis, focusing on English hashtags. As health policy and health communication vary by country, we encourage to conduct regional analysis (e.g., an analysis for Germany). Such an analysis would be enabled by building tools for policy-makers (see above).

Implications for research: The data shows an association between hashtag usage and, for example, events and politics. As an example, the press conferences of President Trump are mentioned in hashtags. We encourage longitudinal studies that explicitly link policy-making and communication to activities and changes on Twitter. Such analysis can reveal how policy-making is perceived and whether it becomes a topic discussed by a wider audience.

Researchers should also focus on drill-down analysis. This study looked at hashtags only. Additionally, the content of the tweet text could be analyzed, e.g., for sentiments. One such example is the study by Saleh et al. [18], who investigated sentiments of tweets related to the tags #socialdistancing and #stayathome.

5. Conclusion

The paper presents an exploratory study of Covid-19 tweets and their hashtags. We looked at hashtag frequencies and identified themes based on hashtags. In total 6.9M hashtags were included in the analysis. We formulated two research questions, which are answered as follows.

RQ1: How frequently hashtags are used? In total 907K different hashtags were used. However, the usage of the hashtags was not balanced. Only very few hashtags were used frequently. We conducted a thematic analysis of the hashtags that were used 1000 or more times, which covered 56% of all hashtag-usages.

RQ2: What are people talking about on twitter? We identified 13 themes of hashtags. The three most frequently used themes were: (1) Covid-19 identifying hashtags, intervention-related hashtags, and hashtags making geographical references.

Based on the data, we discussed health policies, as well as implications for research.

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