A Tale of Two Communities: Characterizing Reddit Response to COVID-19 through /r/China_Flu and /r/Coronavirus

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The COVID-19 pandemic has deeply impacted people’s lives around the globe. During the extended lockdowns caused by the pandemic, online communities are crucial for people to access information and share experiences. In particular, two “new” communities have emerged on Reddit: /r/China_Flu and /r/Coronavirus. By studying activities and users in these two communities, we provide a characterization of people’s responses to COVID-19 on Reddit. First, we find that user activity peaks around March 17, when the World Health Organization (WHO) announced COVID-19 as a pandemic. Shortly after that, the activity levels of both communities have been declining week by week. We further illustrate the central role of these two communities in the emergence of COVID-related communities. Second, we study the differences between these two communities. /r/Coronavirus is recommended as the official community for COVID-19 on Reddit, while /r/China_flu adopts a loose moderation practice. As a result, we observe that these two communities are gradually growing apart and more extremism is being found in /r/China_flu. Finally, we examine the spillover effect of the COVID-19 pandemic on user activity across the entire Reddit platform. Our results show significant changes in user activities outside COVID-related communities. In subreddits related to finance, food, and countries/cities, user activity is recovering to the pre-pandemic level in late April and May as countries reopen, but subreddits related to travel and sports remain highly impacted and show lower activity levels than the pre-pandemic period. Our work highlights the strength of Reddit as a source for understanding public reactions to COVID-19 and the importance of content moderation on the Internet during a pandemic.

CCS Concepts: • Applied computing → Law, social and behavioral sciences; • Human-centered computing → Collaborative and social computing.

Additional Key Words and Phrases: coronavirus, covid-19, pandemic, conspiracy, racism, Reddit

ACM Reference Format:
Jason Shuo Zhang, Brian C. Keegan, Qin Lv, and Chenhao Tan. 2020. A Tale of Two Communities: Characterizing Reddit Response to COVID-19 through /r/China_Flu and /r/Coronavirus. 1, 1 (June 2020), 26 pages.
https://doi.org/10.1145/nnnnnnn.nnnnnnn

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XXXX-XXXX/2020/6-ART $15.00
https://doi.org/10.1145/nnnnnnn.nnnnnnn
INTRODUCTION

In December 2019, a novel coronavirus strain (SARS-CoV-2) emerged in the city of Wuhan, China. The disease (COVID-19) quickly spread all over the world and led the World Health Organization (WHO) to declare a pandemic [63]. By the end of May 2020, 188 countries/regions reported over 6.2 million positive cases and 372,037 deaths [14]. The pandemic is not only exhausting public health resources but also causing social and economic disruption at an unprecedented speed and scale. Governments around the globe have implemented a series of protective measures, such as lockdowns, social distancing, travel bans, and mask-wearing, to contain the spread of the disease.

While medical experts are rushing to treat COVID-19 patients and develop vaccines, social media has been critical for people in accessing information and sharing experiences during the pandemic. Take Reddit as an example, user-created subreddits dedicated to discussing the coronavirus have popped up and attracted millions of subscribers since the beginning of the outbreak. Top posts on these subreddits include AMA (ask me anything) with Bill Gates, medical experts, and politicians. By the end of May 2020, there are over four hundred coronavirus subreddits on the platform, including two major general discussion communities, /r/China_flu and /r/Coronavirus. Others may focus on a specific region, such as /r/CanadaCoronavirus, /r/CoronavirusCA, and /r/CoronavirusNewYork, or a specific topic, such as /r/CoronavirusRecession, /r/CoronavirusMemes, and /r/COVID19_support.

The platform has become one of the most comprehensive and up-to-date sources of information for this constantly developing crisis.

Besides information sharing, social media also provides regular people a sense of normalcy during these challenging times. It can serve as an antidote to physical isolation by allowing people to seek possible job opportunities, keep up with education, and entertain. When outside forces, such as COVID-19, largely break in-person contact, online communication provides an urgently-needed remedy for connecting the world.

However, the impact of social media during this pandemic is not always positive. The ubiquity of social media has made it easy to create and spread COVID-19 falsehoods. The world’s largest social media companies are reportedly under immense pressure to crack down on coronavirus misinformation that has been spread across their platforms [54]. On /r/Coronavirus, Reddit’s official COVID-19 community, a team of more than 60 content moderators, including researchers of infectious diseases, virologists, computer scientists, doctors, and nurses, are spending hours daily removing misinformation, trolls, and discussions [53]. However, despite the joint effort on content moderation from mainstream social media platforms [54], nearly two-thirds of Americans reported that they had seen news and information about the disease that is wholly made up [4]. Many of these misinformation narratives originally surfaced from unregulated platforms, including Gab and 4chan [74] and under-moderated spaces, such as /r/Wuhan_Flu and /r/coronavirusconspiracy [18].

In this work, to characterize public responses to COVID-19 on social media, we construct a large-scale dataset of two Reddit communities that are dedicated to COVID-19 discussions, /r/China_flu and /r/Coronavirus. The dataset contains 312K posts, 7.0M comments, and 573K users. We choose Reddit as our testbed because (1) massive numbers of people turn to Reddit for the latest updates about COVID-19. Take the official community /r/Coronavirus as an example, it has become the fastest-growing subreddit on the entire platform with over 2.1 million subscribers after four months of its creation; (2) Health professionals [68], essential workers [72], and recovered patients [39] are reportedly using Reddit as a primary source to share stories and information; and (3) Reddit is driven by communities and each community has its own moderation rules. In comparison, the content regulation policies on Twitter and Facebook are relatively vague.

**Organization and highlights.** We first describe the background, research questions, and hypotheses. Then we provide an overview of COVID-related subreddits and introduce the dataset that
we collected for this study. We also demonstrate how user activity is connected with the important
dates of this pandemic.

After that, we investigate three research questions in the rest of the paper. First, we provide an
exploratory analysis to understand how coronavirus-related subreddits have emerged during this
pandemic. By investigating the founders of the two earliest COVID-19 communities, /r/China_flu
and /r/Coronavirus, we find that users who have paid attention to the disease from the beginning
are news readers, conspiracy theorists, and survivalists. We have also built a genealogy graph of
COVID-related communities and have found /r/China_flu and /r/Coronavirus to be parents of
many other subreddits related to COVID-19.

Second, we compare the differences between /r/China_flu and /r/Coronavirus, and how these
differences relate to moderation practices implemented in these two communities. Our results show
that the language distance between /r/China_flu and /r/Coronavirus decreased in early February and
then started to increase over time after the moderation practices diverged. /r/China_flu users pay
much more attention to topics related to China and the Chinese government, while /r/Coronavirus
users spend more time discussing the urgency and seriousness of the pandemic. Furthermore,
/r/China_flu has more racist behavior and has a higher overlap with extreme communities compared
with /r/Coronavirus. Intriguingly, many of these differences observed in our study are not apparent
until different moderation practices have been implemented by the platform.

Third, we turn our focus to the entire Reddit platform and examine how people adjust their
activity in response to the pandemic as a proxy of people’s lives during the pandemic. We show
that users who are active in coronavirus-related subreddits also have had a surge of activity in
non-coronavirus subreddits during this pandemic. In addition, we explore the change of user
activity in different categories of online communities. We find significant changes in most of the
categories. In communities related to finance, food, and countries/cities, user activity has recovered
to the pre-pandemic level in late April and May as countries reopen, but communities related to
travel and sports remain highly impacted and show lower activity levels than before the pandemic.

Finally, we offer concluding discussions. Our work develops a framework for characterizing
disaster responses in online discussion forums. The results in our work highlight the strength of
Reddit as a source for understanding public reactions to COVID-19 and examining the spillover
effect on user activity across different categories. Additionally, our work provides clear evidence
that social media may not be neutral in the middle of an international crisis. Proactive content
moderation is associated with preventing the dissemination of racism and conspiracy theories.

BACKGROUND & RESEARCH QUESTIONS

Given the dynamic nature of the COVID-19 pandemic, real-time tracking of public response is
critical. Posts and comments in COVID-related subreddits provide a valuable resource for charac-
terizing the public response. This section reviews three areas that are most relevant to our work:
community genealogy and highly related communities, the effect of moderation practice, and crisis
informatics/sociology of disaster.

Community genealogy and highly related communities

When social media platforms give users the freedom to form interest groups, a series of highly related
communities can emerge. For example, during the 2016 election, a battery of Trump-related commu-
nities emerged on Reddit, such as /r/The_Donald, /r/AskThe_Donald, and /r/AskTrumpSupporters.
The creation, development, and lifecycle of highly related communities have drawn considerable
interest in the research community. The first line of work compares the characteristics of highly
related communities. Hessel et al. [21] investigate the interactions between highly related Reddit
communities and identify patterns of affixes being used in their names. The work by Zhang et al.
[77] focuses on online NBA fan communities and analyzes how fans of different teams react to team performance. The second line of research studies the impact of membership overlap between highly related communities. Haiyi Zhu, Robert Kraut, and collaborators investigate shared membership in online communities on a variety of platforms and propose strategies for long-term community survival [30, 79–81]. The final line provides a global overview of how users move through the space of communities and how new communities emerge from the old ones. For example, Tan and Lee [61] use several temporal features across communities to predict users’ activity levels and departure from Reddit. To visualize the process of how new communities develop from old ones, Tan [59] proposes a computational approach for building genealogy graphs between communities.

As the COVID-19 pandemic evolves, over four hundred coronavirus-related subreddits have popped up. Besides /r/China_flu and /r/Coronavirus, there are region-specific subreddits, such as /r/CoronavirusUK, /r/CoronavirusCA, and /r/CoronavirusNewYork. There are also subreddits focusing on a certain aspect of the pandemic, such as /r/CoronavirusMemes, /r/CoronavirusRecession, and /r/COVID19positive. Following the rise of these subreddits, we formulate our first research question as follows:

RQ1: How do coronavirus-related communities emerge during the COVID-19 pandemic?

The effect of moderation practice

On online platforms that invite users to post comments, a moderation mechanism involves the monitor of various content, including written opinions, reviews, videos, and pictures, according to a pre-determined set of rules and regulations. It may also be under external requirements, like removing content that violates local, national, and international laws [71]. Content moderation is critical in the development of a healthy environment as it protects users from being harmed and ensures the quality of content [23–25, 30, 55]. Lack of such regulation can expose users to unpleasant information and exhaust their limited attention. In a recent example, /r/worldpolitics is overwhelmed with NSFW (not safe for work) posts featuring porn pictures as moderators allow for all sorts of inappropriate content to be submitted [13].

There has been an impressive body of research to understand the effect of moderation. For example, Jhaver et al. [23, 25] employ survey- and platform-based approaches and find that users who receive explanations for content removal are more likely to post again in the future. They further examine the role that Automodulators play in content moderation and identify a list of advantages and challenges [24]. Juneja et al. [28] reveal the lack of transparency in moderation practices on Reddit, which impede moderators’ ability to be fair. The study by Phadke and Mitra [47] portray cross-platform efforts by online hate groups for recruitment and growing influence due to the lack of censorship and moderation. From the technical perspective, various approaches have been proposed to improve the performance of moderation, such as tagging [75], summarization [76], distributed moderation [32], and crowdsourcing [33, 37].

In our work, /r/China_flu and /r/Coronavirus provide a natural experiment for examining how moderation practice shapes online communities. Both of these two communities are COVID-19 centric, which indicates similar discussion topics broadly. However, /r/China_flu allows more relaxed discussions while /r/Coronavirus implements strict moderation rules (Figure 1). This observation motivates us to study the difference between these two subreddits:

RQ2: How do /r/China_flu and /r/Coronavirus differ during the COVID-19 pandemic?

Earlier studies find that lack of effective moderation may produce a large amount of low-quality content in the online space, such as conspiracy theories, racist content, and misinformation [23, 24, 30, 73]. For example, NPR, CNN, Reuters, and other news sites eliminate their online comment
section due to inappropriate content [34]. The well-known unregulated website 4chan.org is responsible for some of the largest hoaxes, conspiracy theories, cyberbullying incidents, and Internet pranks of the past few years [42]. Therefore, we formulate our first hypothesis as follows:

**H1:** Due to the loose moderation practice, /r/China_flu will have more conspiratorial discussions and racist behavior than /r/Coronavirus.

Online communities are in constant flux [11]. New members who join a community need to adapt to existing community norms, and old members who do not like the trajectory of the development will depart. Given the lack of restriction in /r/China_flu, extreme users may be more likely to join /r/China_flu and remain active there. Meanwhile, members who are looking for serious discussions about the pandemic may leave. Accordingly, we expect /r/China_flu to attract more users from extreme communities than /r/Coronavirus:

**H2:** /r/China_flu has a higher overlap with extreme communities than /r/Coronavirus.

**Crisis Informatics & Sociology of Disaster**

According to a 2018 United Nations Review, the frequency of disasters is on the rise globally [15]. Disaster events and their economic impacts are trending topics in computational social sciences. In the early days of crisis informatics research, qualitative methods, such as descriptive surveys and interviews, were the main source of data collection [44, 45, 57]. Recently, following the advancement of the Internet and mobile technology, social media has played a critical role in the flow of public information. A growing percentage of citizens frequently turn to these platforms for emergency updates [31, 50]. To effectively analyze information on mass media, computational approaches have been widely adopted in crisis informatics. For example, Vieweg et al. [67] analyze public responses to two disaster events, the Red River Floods and the Oklahoma Grassfires, using Twitter communications. Hagen et al. [17] propose a network analysis approach to identify a number of distinct communities and influential actors using Zika-related tweets. Stewart and Wilson [56] characterize how citizens utilize social media to redistribute emergency updates and connect with family and friends during Hurricane Sandy.

The COVID-19 pandemic has caused catastrophic social and economic disruption around the globe. As reported by the International Monetary Fund, the world is going through the worst global recession since the Great Depression in the 1930s [16]. The pandemic has led to cancellation or postponement of school, religious, political, and sporting events and supply shortages exacerbated by panic purchasing [5, 22, 43]. During the pandemic, social media platforms such as Twitter and Reddit, have not only become primary sources of information but also serve as destinations for companionship and entertainment purposes. As a result, users’ activity on Reddit may reflect how their normal life is being affected. Additionally, when countries began phased reopenings in late April and May, would users’ activity on Reddit return to the pre-pandemic norm?

**RQ3:** How do people change their activity during the pandemic over time, and how does it relate to their membership in /r/China_flu and /r/Coronavirus?

As the stay-at-home order begins, people have more time to tune into social media to connect with friends, family, and like-minded individuals for socialization and emotional support. Several major social media platforms have observed traffic escalation [29, 58, 62]. We expect the increment happens not only to coronavirus-related subreddits, but also to non-coronavirus subreddits. We propose the third hypothesis as follows:

**H3:** People who are active in coronavirus-related subreddits also have a surge of activity in non-coronavirus subreddits during the COVID-19 pandemic.
More importantly, the user activity on different categories of online communities can be a direct reflection of the socio-economic effects of COVID-19 on daily life. For example, as the unemployment rate keeps soaring, people who lost jobs may check economy-related communities more often. Some sports fans may stop checking sports-related communities as most sporting events are suspended. In a recent survey review, Nicola et al. [43] summarize the effect of COVID-19 on individual aspects of the world economy in tertiary sectors, which are divided into eight categories: Education, Finance, Healthcare, Travel, Housing, Sports, Technology, and Food. With this list, we find subreddits that are highly relevant to each category based on the wiki page of /r/ListOfSubreddits 1. This page provides a summary of various kinds of popular subreddits. We do not find a popular subreddit related to Housing or Healthcare on this page. Thus, these two categories are removed. We also add three additional categories that are specific to the Reddit culture: Humor, TV/Movie, and Countries/Cities. All these three categories attract a vast audience on the Reddit platform. For example, /r/funny is one of the largest subreddits, with more than 30 million subscribers.2 /r/TV and /r/movies each has more than 15 million subscribers. Additionally, almost all major countries/cities can find their corresponding subreddits.3

Social distancing, quarantine, travel restrictions, and stay-at-home order have led to a reduced out-home activity across many categories. In an attempt to control the spread of the disease, most governments around the world have temporarily closed educational institutions [65]; more than 90% of the people worldwide live in countries with travel restrictions [10]; many influential sports leagues have postponed or canceled sporting events [70]; food and restaurants have been forced to close or only take carry-out orders [7]. Therefore, we hypothesize subreddits related to out-home activities to draw less attention during the pandemic:

**H4.a:** For categories in which events are mostly out-home and mobile, users will show less interest in corresponding subreddits. Such categories include Education, Travel, Sports, and Food.

While much out-home activity is disrupted, people are finding creative ways to study, work, connect, and entertain at home. Online technology platforms become our best chance of staying together and enduring difficult times. Events that can be conducted on the Internet may have a unique advantage during the COVID-19 outbreak:

**H4.b:** For categories in which events are mostly online or related to stay-at-home and work-from-home, their subreddits will have a surge of activity. Such categories include Finance, Technology, Countries/Cities, TV/Movie, and Humor.

**APPROACH**

Our main dataset is drawn from Reddit,4 a community-driven forum for discussion, news consumption, and content rating. It was founded in 2005 and has become the 21st most popular websites in the world in May 2020 [1]. There are tens of thousands of communities (known as subreddits) on Reddit dedicated to a wide variety of topics. Users can submit, comment on, upvote, and downvote content in each subreddit.

/r/China_flu and /r/Coronavirus

Since the outburst of COVID-19 in late January 2020, a series of COVID-related communities have emerged and drawn substantial public attention. In this study, we focus on two communities,
Characterizing Reddit Response to COVID-19 through /r/China_Flu and /r/Coronavirus

Table 1. Dataset Statistics. Here #users refers to the number of unique users who posted/commented in /r/China_flu and /r/Coronavirus, respectively.

|           | #posts | #comments | #users |
|-----------|--------|-----------|--------|
| /r/China_flu | 73K    | 1.2M      | 72K    |
| /r/Coronavirus | 239K   | 5.8M      | 542K   |

(a) Reddit makes /r/Coronavirus the official community for COVID-related updates.

(b) Reddit allows more relaxed discussions in /r/China_flu.

Fig. 1. On February 17th, the Reddit platform decides to make /r/Coronavirus the official community for COVID-related updates. All the posts submitted to /r/Coronavirus are heavily moderated (Figure 1a). Meanwhile, the platform allows more relaxed discussions in /r/China_flu (Figure 1b).

/r/China_flu\(^5\) and /r/Coronavirus\(^6\), which are dedicated to COVID-related information from the very beginning of this global pandemic. /r/China_flu was founded on January 20th, 2020, when news about the first breakout of COVID-19 emerged in Wuhan, China. /r/Coronavirus was founded on May 3rd, 2013, but remained inactive most of the time. The first post in /r/Coronavirus since 2017 is about COVID-19 on January 20th, 2020. We collect all the posts and comments submitted to these two subreddits from January 20th to May 24th in 2020 from pushshift.io\(^8\). Table 1 gives a summary of the statistics about these two subreddits.

Important Dates

On February 17th, the Reddit platform has decided to make /r/Coronavirus the official community for COVID-related updates on the website. Users who search for COVID-related keywords have been recommended to check out /r/Coronavirus (Figure 1a) since then. The subreddit is described as the place for high-quality discussions. All the posts and comments submitted are strictly moderated. Meanwhile, the platform allows more relaxed discussions in /r/China_flu (Figure 1b). This policy shift is reflected by user activity in these two subreddits. As illustrated in Figure 2, the weekly number of posts and comments in these two communities are at a similar level before the February

\(^5\) On the front page of /r/China_flu ([https://www.reddit.com/r/China_Flu/](https://www.reddit.com/r/China_Flu/)), it explains that “The name /r/China_flu was created at a time when SARS-CoV-2 had not been named and was only affecting China. Subreddit names cannot be changed after they are created.”

\(^6\) [https://www.reddit.com/t/coronavirus/](https://www.reddit.com/t/coronavirus/).
Fig. 2. Figure 2a and Figure 2b shows the number of posts and comments per week, respectively, in /r/China_flu and /r/Coronavirus. Before the February 17th announcement, user activity is at a similar level between these two subreddits. After the announcement, /r/Coronavirus becomes much more popular than /r/China_flu. The overall user activity starts declining in both subreddits around March 9th. It may be due to people’s fatigue of COVID-related topics.

On March 11th, the World Health Organization declared COVID-19 as a global pandemic [63]. User activity in /r/Coronavirus peaks at that week. Interestingly, after that week, user activity keeps dropping. It may be due to people’s fatigue of COVID-related topics. According to a study released by the Pew Research Center at the end of April, 71% of Americans say they need to take breaks from news about the coronavirus, and 43% say they feel worse emotionally as a result of following the news [4]. In comparison, the posting activity in /r/China_flu shows a similar trend, and the comment activity starts to go down even earlier, from the week of February 24th.

Other COVID-related subreddits
To understand how COVID-related subreddits emerge from /r/China_flu and /r/Coronavirus, we also collect posts and comments from a set of Coronavirus-related subreddits. We use two ways to search for popular Coronavirus-related subreddits. The first set of subreddits are identified at the sidebar of /r/Coronavirus. We also find all subreddits whose names start with “covid” or “coronavirus”. After combining these two sets of coronavirus-related subreddits, we rank them based on their total number of comments and select the top-7 regional-specific subreddits and top-7 general related subreddits. These 16 subreddits will be used for visualizing the genealogy graph between in Figure 5. For each of these subreddits, we collect its entire posting and commenting history from the creation date to May 24th, 2020.

We will share all our processed data and code upon publication.

RQ1: THE EMERGENCE OF CORONAVIRUS-RELATED COMMUNITIES
We start with an exploratory analysis to understand how coronavirus-related communities emerge during this pandemic. We first examine the weekly overlap and common news articles between /r/China_flu and /r/Coronavirus to understand the composition of these two communities. Second, we look at the founders of these two subreddits and check which communities they came from before joining /r/China_flu and /r/Coronavirus, respectively. Finally, we characterize the genealogy
(a) The weekly proportion of overlapping users between /r/China_flu and /r/Coronavirus.  

(b) The weekly proportion of common news articles that are posted in both /r/China_flu and /r/Coronavirus.

Fig. 3. Figure 3a shows the weekly overlap between /r/China_flu and /r/Coronavirus. The overlap is measured by the proportion of users who are active in both communities. Figure 3b shows the weekly proportion of common URLs that are posted in both /r/China_flu and /r/Coronavirus.

The weekly overlap between /r/China_flu and /r/Coronavirus

Figure 3a shows the weekly overlap between /r/China_flu and /r/Coronavirus. The overlap is measured by the proportion of users in one community that are also active in the other community in the same week. Around the week of March 2nd, more than 40% of /r/China_flu users are also active in /r/Coronavirus. After that week, the overlap keeps going down over time. This trend indicates that the separation between /r/China_flu and /r/Coronavirus widens as the pandemic develops.

We also examine the weekly proportion of news articles shared in both communities. We define a news article to be shared by both communities by finding a pair of posts, one from /r/China_flu, one from /r/Coronavirus, which have the exact same URL (linking to the same news article). Figure 3b illustrates that an increasing proportion of news articles posted in /r/China_flu are also submitted to /r/Coronavirus. In contrast, /r/Coronavirus covers more diverse COVID-19 stories as around 90% of its news articles are not shared in /r/China_flu.

Founders of /r/China_flu and /r/Coronavirus

To understand where the founders of /r/China_flu and /r/Coronavirus came from, Figure 4 shows the top-10 parents of these two communities. These top-10 parents are selected based on each community’s first 50 members’ activity on Reddit one week before joining /r/China_flu or /r/Coronavirus. Interestingly, the founders of /r/China_flu and /r/Coronavirus were both active in /r/collapse, a subreddit that attracts survivalists to discuss the potential collapse of global civilization. It suggests that people who pay attention to this virus at the very beginning tend to worry about the break down of our society in general [12]. Unsurprisingly, early members of /r/China_flu and /r/Coronavirus...
Fig. 4. Figure 4a shows the top-10 subreddits that the first 50 users of /r/China_flu had been active in one week before joining /r/China_flu; Figure 4b shows the top-10 subreddits that the first 50 users of /r/Coronavirus had been active in one week before joining /r/Coronavirus.

are also active members of news-related subreddits (/r/worldnews and /r/news). This explains why they were aware of this new disease the earliest. Moreover, eight founders of /r/China_flu were also active in /r/conspiracy, indicating that COVID-19 topics attract conspiracy theorists [35, 41], particularly in /r/China_flu. In comparison, /r/China is among the top-10 parents of /r/Coronavirus, suggesting that individuals who are invested in China started to avoid /r/China_flu from the very beginning.

Genealogical graphs
Since /r/China_flu and /r/Coronavirus are the two earliest communities that concentrate on COVID-related discussions, it would be useful to explore how other COVID-related subreddits emerge from them on the platform. Following Tan [59], Figure 5 presents a broader view of a genealogy graph. The graph is based on the first 50 members of each COVID-related subreddit. A directed edge indicates that there exist early members of the “child” subreddit who were members of the “parent” subreddit. The thickness of an edge represents the fraction of such members. The node size indicates the community size measured by the number of active members. To improve the readability of the graph, we remove edges with less than 0.02 weights, which is less than or equal to one member from the parent subreddit.

In general, we can see that this genealogy graph is very dense. /r/China_flu and /r/Coronavirus are indeed parents of many communities related to COVID-19. It also shows that both communities attract users from all over the world. Some exceptions are interesting: /r/Coronavirus is not a parent of /r/CoronavirusMemes, and the edge between /r/China_flu and /r/CoronavirusMemes is thin. Founders of /r/CoronavirusMemes are not from coronavirus-related subreddits. Moreover, the edge from /r/China_flu to /r/CoronavirusRecession is thinner than the one from /r/Coronavirus to /r/CoronavirusRecession. We see similar trends when plotting the genealogy graph using the post activity (Figure 11 in the appendix).

RQ2: THE DIFFERENCE BETWEEN /R/CHINA_FLU AND /R/CORONAVIRUS
Even though both /r/China_flu and /r/Coronavirus are COVID-19 centric, we have seen in RQ1 that the overlap between these two communities decreases over time. In this section, we investigate
hypotheses about their differences driven by moderation practices. We expect them to develop different norms, formulate different language styles, and stimulate further changes to the membership and social dynamics over time.

We first compare the language usage difference between /r/China_flu and /r/Coronavirus and examine how it evolves. Then we conduct a qualitative analysis of over-used keywords, the most downvoted comments, and replies to moderators in each community. After that, we compare the weekly overlap between these two communities and some more extreme communities on Reddit. Overall, we observe an increasing difference when comparing these two subreddits. /r/China_flu cares more about topics related to China or the Chinese government, generates more racist comments, and has higher overlap with other extreme communities. Many of these differences are not apparent until different moderation practices are implemented by the platform.

Language usage

Because posting comments is a major activity for users on Reddit, we first characterize two communities’ behavior differences through the lens of language usage. **Language distance.** First, we measure the language distance between /r/China_flu and /r/Coronavirus. Intuitively, since both communities are COVID-19 centric, we would expect their word usage to follow similar distributions. It would be surprising if one word frequently appears in /r/China_flu but not in /r/Coronavirus and vice versa. The existence of such words indicates a larger language distance. Similar to prior work [3, 6, 60], we adopt the Jensen-Shannon Divergence [38] to measure the weekly unigram usage difference in comments between these two subreddits. For all text-related computations in this paper, we remove punctuation marks and stopwords, and stem the words during preprocessing. The preprocessing is implemented using Gensim [49]. We also remove comments from moderators or bots to focus on natural users’ responses during this pandemic.

Figure 6 summarizes the weekly language distance between /r/China_flu and /r/Coronavirus, as measured by the Jensen-Shannon Divergence. Interestingly, the language distance decreases slightly before the week of February 24th. This suggests that the word usage between these two communities are similar at that time. After that, the language distance keeps going up, indicating an increasing difference between these two subreddits. Intriguingly, the peak similarity appears in...
the week of February 24th, one week after the February 17th official announcement (Figure 1). The strict moderating rules implemented in /r/Coronavirus and allowing more relaxed discussions in /r/China_flu may play a role for this shift. The final decline in May is likely driven by the reduction of activities in both communities.

**Classification models.** Another way to estimate the language distance between /r/China_flu and /r/Coronavirus is to measure the separation of comments in each community. We formulate a binary classification task: given the aggregation of comments under one post, can we determine which community this post comes from? For each week, we randomly sample 2000 posts from /r/China_flu and /r/Coronavirus, respectively. Each post is represented by the aggregation of all the comments it receives (posts without any comments are removed before the sample). To make sure that the number of comments in each post does not play an important factor in our classification model, we randomly sample 20 comments of each post. This task is thus a balanced classification task, where the majority baseline accuracy is 50%.

The feature set for this task is bag-of-words (BOW) from aggregated comments. To assess each week’s classification performance, we measure accuracy in five-fold cross-validation using a standard $\ell_2$-regularized logistic regression classifier.

Figure 7a presents the weekly accuracy of determining which community a post came from given its aggregated comments. We observe a similar trend compared with using Jensen-Shannon Divergence: Before the week of February 24th, the accuracy is decreasing, indicating that the language difference between /r/China_flu and /r/Coronavirus is hard to classify. After the week of February 24th, the accuracy goes up, indicating an increment of distinction. Different from the Jensen-Shannon distance, we observe that the classification performance between these two communities converges at around 65% since March.

With each week’s classification model trained, we also evaluate the cross-week performance. As illustrated in the heatmap Figure 7b, we use the classification model trained on “week1” to classify the aggregated comments in “week2”. The accuracy is low (close to chance) in the top right corner. These results suggest dramatic change in these two communities before and after the February
Characterizing Reddit Response to COVID-19 through /r/China_Flu and /r/Coronavirus

Fig. 7. Figure 7a shows the weekly accuracy of determining which community (/r/China_flu or /r/Coronavirus) a post’s aggregated comments come from using BOW. Before the week of February 24th, the accuracy is decreasing, indicating that the language difference between these two communities is hard to classify. After the week of February 24th, the accuracy goes up, showing an increment of distinction. We run this classification model until the week of April 6th as there are not enough posts in /r/China_flu after that week to perform this task. Figure 7b shows the cross-week accuracy of differentiating comments posted to /r/China_flu or /r/Coronavirus using BOW. In this heatmap figure, every cell indicates the accuracy of using the classification model trained on “week1” to classify the comments in “week2”. The weeks before February 17th have relatively good performance when classifying each other. And a similar pattern applies to the weeks after February 24th. However, when we use a classification model before February 17th to classify the comments after February 24th and vice versa, the performance is poor.

Qualitative validation of over-represented keywords. To get a better sense of how /r/China_flu and /r/Coronavirus members talk differently, we supplement with qualitative analyses. To identify a list of keywords that are over-used by members in /r/China_flu and /r/Coronavirus, we implement the Fightin’ Words model [40] to compare one community’s word frequencies to the other community using the informative Dirichlet prior model. The Fightin’ Words model is effective in detecting word usage differences between two corpora by introducing a smoothing Dirichlet prior on vocabulary items. This method avoids over-emphasizing fluctuations of rare words, a challenge faced by traditional methods such as PMI [38] and TF-IDF [51]. Recently, the Fightin’ Words model has been frequently used in analyzing language usage in online communities [20, 36, 78].

Table 2 presents the weekly over-used keywords in /r/China_flu and /r/Coronavirus. Due to the space limit, we show results every three weeks. After the February 17th announcement, members in /r/China_flu pays much more attention to China-related topics. Many of the over-represented keywords are related to China or the Chinese government. This finding echoes prior research about the emergence of Sinophobic behavior on Twitter and 4chan during the outbreak of the COVID-19 pandemic [48, 52]. However, we do not see such words in the first two weeks in the table. In comparison, in the week of February 17th, many keywords in /r/Coronavirus are related to content moderation. Given that we already remove all the comments from moderators or bots during preprocessing, these words can be members arguing for/against strict rules and quality control. After that week, members in /r/Coronavirus spend more time discussing topics related to daily life (e.g., school, work, home, and grocery).
Table 2. The weekly top-10 over-used words in /r/China_flu and /r/Coronavirus, respectively. These words are selected and ranked by the z-scores calculated using the Fightin’ Words model [40]. These words are stemmed before fitting into the model.

| Keywords over-used in /r/China_flu | 01/27 | 02/17 | 03/09 | 03/30 | 04/20 | 05/11 |
|-----------------------------------|-------|-------|-------|-------|-------|-------|
| case                              | mike  | china | china | china | china | china |
| test                              | econom| mod   | chines| chines| chines| chines |
| suspect                           | hummu | applic| ccp   | ccp   | ccp   | ccp   |
| provinc                           | scream| mask  | taiwan| taiwan| taiwan| taiwan |
| mistak                            | trump | permit| lab   | communist | feedback | communist | 
| mild                              | peopl | ccp   | wuhan | feedback | wuhan | feedback |
| travel                            | shave | prep  | communist | world | trump | 
| patient                           | tree  | advic | bat   | racist | mod   | beij   |
| thread                            | racism| wuhan | racist | mod   | war   | 

| Keywords over-used in /r/Coronavirus | dont | remov | test | home | peopl | social |
|--------------------------------------|------|-------|------|------|-------|--------|
| mask                                 | post | school| stai | week | counti|        |
| kill                                 | suit | polit | week | job  | home  |        |
| viru                                 | coronavirus | polic | groceri | stai | dai   |        |
| eat                                  | reliable | trump | dai  | work | risk  |        |
| video                                | announc | cancel | store | open | live  |        |
| food                                 | cooper | conti | peopl | home | pai   |        |
| anim                                 | mistak | symptom | essenti | death | care  |        |
| prepar                               | sourc | work | test | state | bar   |        |
| dead                                 | artic | close | conti | hospit | texas |        |

Replies to moderators. What kind of comments were removed in /r/China_flu and /r/Coronavirus? In both communities, moderators usually explain the decision with a reply to the removed comment. However, the explanation is usually generic (e.g., “Incivility isn’t allowed on this sub”) and it is difficult to know the exact reason. To answer this question, an alternative approach is to look at people’s responses to moderators’ explanations. We note that even if a comment is removed, the responses to this comment will still be available on the platform. In those responses, users usually present a rebuttal of why their content does not violate the rules. We identify 708 such responses in /r/China_flu and 2,275 such responses in /r/Coronavirus.

We again run the Fightin’ Words model to find a list of distinguishing keywords that are over-used by each community. Our results are shown in Table 3. In /r/China_flu, over-represented keywords in responses to moderators are highly related to China or the Chinese government. They also connect with some popular conspiracy theories about COVID-19, such as the virus comes from a Wuhan lab, the virus comes from people eating bats, or the virus is a foreign bioweapon [35]. Additionally, when we read through these responses, many users are arguing that their comments are not meant to be racist. Comparatively, most of the over-used keywords in /r/Coronavirus are about arguing the quality of the content or whether it is political. There are also users complaining that their comments are not conspiracy theories or not uncivil. A random sample of responses to moderators in each community are attached in Appendix (Table 5).

Most downvoted comments in each community. By design, Reddit communities allow users to vote up or down for the comments they read. The difference between the number of upvotes and downvotes a comment receives is referred to as “score.” The ranking system will display comments with the highest scores at the top of the page and hide the ones with the lowest scores. The most
Table 3. The top-20 over-used words in replies to moderations in /r/China_flu and /r/Coronavirus. These words are selected and ranked by the z-scores calculated using the Fightin-Words algorithm [40].

| Keywords | Over-used keywords in replies to moderations in /r/China_flu | Over-used keywords in replies to moderations in /r/Coronavirus |
|----------|-----------------------------------------------------------|-----------------------------------------------------------|
| lab, china, viru, flu, wuhan, relat, topic, bat, racist, countri, ccp, hospit, claim, effort, protect, rule, weapon, freedom, cfr, advertis | titl, post, qualiti, polit, articl, repost, high, conspiraci, sourc, video, gui, remov, sorri, edit, provid, translat, info, state, uncivil, pure |

Table 4. Most downvoted comments in /r/China_flu and /r/Coronavirus.

| Score | Comment |
|-------|---------|
| -104  | 1. Focus less on China and more on your US. You are on brink of collapse. |
| -103  | 2. You know what? You guys can talk about any government you would like but when you bring in a large group of people that is racism. That is not tolerated on this sub. Neither is Xenophobia, just because someone does something different from you does not make it wrong. |
| -97   | 3. Thought you guys claiming he was kidnapped by the big bad wolf CCP. Turns out he was forced quarantined so he doesn’t go out spreading the virus like a dumbass. Like what is happening in America. |
| -93   | 4. Is there a real problem? China preferred money and they’re getting what they want. Donation is giving away something for free without any requirement or expectation of reciprocity. |
| -91   | 5. Western countries got hit hard because the gov disregard Chinese government’s advice and refused to ask people to wear masks, not because they got news late. |
| -467  | 1. the peak has passed, open the country |
| -452  | 2. The US response to the Corona Virus has been far better and more timely than most countries. The government will never look good no matter the response. Death never looks good. When the government did respond, they were attacked by the media for acting to harsh... |
| -431  | 3. The Coronavirus is very much under control in the USA. We are in contact with everyone and all relevant countries. CDC and World Health have been working hard and very smart. Stock Market starting to look very good to me! |
| -357  | 4. I mean it feels like 99% of the world downplayed the virus. The see-I-told-ya-so’s can apply to lots of people. I don’t see the point of it now. |
| -324  | 5. A mix of medias have both downplayed the virus at some point. There is no use in making this into a political fight... people make judgments on limited information and then shit hits the fan, it happens to everyone, there is no use in pointing fingers and wishing bad on anyone. |

Downvoted comments can help us understand what opinions that the community members dislike intensely.

The most downvoted comments in /r/China_flu and /r/Coronavirus are listed in Table 4. Interestingly, all five comments in /r/China_flu are related to saying positive things about China or the Chinese government. In contrast, downvoted comments in /r/Coronavirus are mostly about downplaying the seriousness of the virus. These results provide further evidence that members in /r/China_flu pay much closer attention to Chinese-related news and have a negative opinion against China. It also explains the higher percentage of Sinophobic behavior observed in /r/China_flu.
We also check the most upvoted comments in each community, which is attached in Appendix (Table 6). The topics that are heavily endorsed in both communities are more diverse.

**Overlap with other extreme communities**

Given that members in /r/China_flu seem to have more radical behavior, such as promoting conspiracy theories and posting racist content, we explore its membership overlap with other extreme communities on the platform. The extreme communities that we consider include:

- **/r/Wuhan_Flu**. /r/Wuhan_Flu is also a COVID-19 centric community. Founders of /r/Wuhan_Flu claim this community a place for “uncensored” discussion. The subreddit was “quarantined” by Reddit four days after its creation, due to “misinformation and hoax content”.
- **/r/conspiracy**. /r/conspiracy is a community devoted to a wide range of conspiratorial discussions. Dramatic events frequently talked about there include JFK, UFOs, and 9/11.
- **/r/collapse**. /r/collapse focuses on discussing the potential collapse of global civilization. The community defines collapse as “a significant decrease in human population and/or political/economic/social complexity over a considerable area, for an extended time”. Some topics frequently discussed in /r/collapse are similar to that of /r/conspiracy.

Figure 8 illustrates /r/China_flu’s and /r/Coronavirus’ weekly user overlap with these three extreme subreddits. /r/China_flu has a much higher overlap with /r/Wuhan_Flu than /r/Coronavirus (Figure 8a), even after /r/Wuhan_Flu was quarantined by Reddit in the week of February 3rd due to the spread of misinformation and hoax content. /r/China_flu also has a much higher overlap with /r/conspiracy than /r/Coronavirus after the February 17th announcement (Figure 8b). Moreover, the proportion of overlap users is increasing steadily after that week. We see a similar trend between the overlap of /r/China_flu and /r/collapse (Figure 8c), except that the increase starts in the week of March 2nd. Interestingly, /r/Coronavirus’ user overlap with /r/conspiracy and /r/collapse is also trending up after March 2nd. This finding echoes previous studies that the spread of conspiracy theories is a widespread problem in coronavirus-related discussions [46, 52]. However, this problem is more salient in /r/China_flu than in /r/Coronavirus, suggesting that these discussions on conspiracy theories tend to occur in relatively smaller communities with loose moderation practice.

**RQ3: HOW PEOPLE CHANGE THEIR ACTIVITY DURING THIS PANDEMIC OVER TIME?**

Finally, we examine how COVID-19 affects people’s life beyond discussions related to coronavirus. The COVID-19 pandemic has caused many cities worldwide to implement strict lockdown to control the spread of this disease. With more time spent indoor, people likely have adjusted their behavior. To measure users’ activity change before and during the pandemic, we collect all /r/China_flu members’ commenting history on Reddit since November 1st, 2019. We filter users who posted no comments in the entire month of November 2019 to focus on users who were already active on Reddit before the pandemic. After this removal, there are 42,748 /r/China_flu members left. Among them, 16,594 members have not posted any comment in /r/Coronavirus. The remaining 26,154 members have commented in both communities. We also randomly sample 16,594 members in /r/Coronavirus who have no comments in /r/China_flu and have been active since November 2019. In our analysis, we compare the weekly activity change of the following three groups of users:

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7 https://www.reddit.com/r/Wuhan_Flu/
8 https://www.reddit.com/r/conspiracy/
9 https://www.reddit.com/r/collapse/
\( H4.a \) which supports our hypothesis.

Interestingly, the activity correlation between /r/China_flu and /r/Coronavirus after the February 17th announcement. The proportion of overlapping users is much higher outside the COVID-19 communities.

Interestingly, the activity correlation between /r/China_flu and /r/Coronavirus after the February 17th announcement. The proportion of overlapping users is much higher outside the COVID-19 communities.

Figure 8a shows that /r/China_flu has a much higher overlap with /r/Wuhan_Flu than /r/Coronavirus. /r/Wuhan_Flu is a community quarantined four days after its creation due to misinformation and hoax (purple line). Figure 8b shows that /r/China_flu has a much higher overlap with /r/conspiracy than /r/Coronavirus after the February 17th announcement. The proportion of overlapping users exhibits an increasing trend. Figure 8c shows that /r/China_flu has a much higher overlap with /r/collapse than /r/Coronavirus since the very beginning of this pandemic. The proportion of overlapping users exhibits an increasing trend since the week of March 2nd.

- **All**: 16,594 users who have only commented in /r/China_flu + 16,594 users who only commented in /r/Coronavirus + 26,154 users who commented in both.
- **/r/China_flu-only**: 16,594 users who have only commented in /r/China_flu.
- **/r/Coronavirus-only**: 16,594 users who have only commented in /r/Coronavirus.

For each comparison, we quantify the change of activity using increase rate, which is measured by the percentage increase of the weekly average number of comments before and during the pandemic: 

\[
\text{increase rate} = \frac{\text{average number of comments in week } j - \text{average number of comments in week } i}{\text{average number of comments in week } i},
\]

where \( N_j \) represents the average number of comments in week \( j \). In our definition, all the weeks before January 27th (when the outbreak starts in Wuhan, China) are before the pandemic, and the remaining weeks are during the pandemic. To understand how activity trends differ between members of /r/China_flu and /r/Coronavirus, we calculate the Pearson correlation coefficient (Corr) between the weekly average number of comments of /r/China_flu-only users and /r/Coronavirus-only users.

Figure 9a shows users’ weekly number of comments in all subreddits since November 2019. We observe a notable increase in overall activity on Reddit during the pandemic compared to before the pandemic (23% increase). This trend is consistent for both /r/China_flu-only users (11% increase) and /r/Coronavirus-only users (11% increase). The trend is similar to Figure 2 as it peaks at the week of March 9th and then starts going down. It suggests that as countries are reopening in April and May, user activity on Reddit is returning to the pre-pandemic norm. Figure 9b and Figure 9c show that the surge of activity is more than following COVID-related updates. In non-coronavirus subreddits, the weekly average number of comments also has a 9% boost during the pandemic. Interestingly, the activity correlation between /r/China_flu-only users and /r/Coronavirus-only users is much higher outside the COVID-19 communities.

Figure 10 summarizes users’ activity change in different categories of comments. We observe varying shapes among these categories. The increase rates for Travel and Sports are negative, which supports our hypothesis \( H4.a \). As extensive travel and sporting events are canceled, users pay less attention to these subreddits accordingly. In April and May, even though many countries are reopening their economic activity, travel and sports events do not recover. Subsequently, user...
activity in these two categories remains at a low level. Among these three categories, we observe similar trends between /r/China_flu-only and /r/Coronavirus-only users as the Pearson correlations are all above 0.60.

In H4.a, we also hypothesize a decline in user activity in Education and Food subreddits. However, the results in Figure 10c and Figure 10d do not support this hypothesis. We observe a 10% increase in the Education subreddits and little change in the Food subreddits (2% increase rate). In Figure 10c, there is an apparent surge of activity between two yellow lines. As COVID-19 starts to become a serious problem in Europe and the U.S., people may flock to the Education subreddits to discuss issues about school closure and students going home. After that, the discussion in the Education subreddits recovers to an average level, similar to the pre-pandemic period. When we compare user activity of /r/China_flu-only and /r/Coronavirus-only users in the Education subreddits, /r/Coronavirus-only users maintain a high level of interest during the pandemic while many /r/China_flu-only users shift their focus away after the week of March 9th. In Figure 10d, we see some drop of activity around the week of March 9th, but it quickly recovers. Even though restaurants and cafes are forced to close, there is a massive demand for food in grocery stores and supermarkets. The shortage of food supply may also prompt discussions in online communities. These factors may mitigate each other in the Food subreddits.

The increase rates for Finance, Countries/Cities, and Humor are positive, which supports our hypothesis in H4.b. These results indicate that people pay more attention to economic opportunities and local news during this pandemic. They are also pursuing funny stories, perhaps for relieving mental and physical stress. Interestingly, user activity in these three categories starts dropping in late April and May. As countries are opening up, people may be less worried about financial issues, follow less local news, and spend less time on memes, jokes, and funny stories. Among these three categories, the patterns of /r/China_flu-only and /r/Coronavirus-only users are similar, as the Pearson correlations are all above 0.50.

In H4.b, we expect an increment in Technology and TV/Movie subreddits. However, the results in Figure 10h and Figure 10i refute our hypotheses. There is no significant change in the Technology subreddits before and during the pandemic (-1% increase rate) and an 18% drop in the TV/Movies subreddits. Notably, /r/China_flu-only and /r/Coronavirus-only users exhibit opposite trends in the

Fig. 9. The weekly average number of comments for three groups of users since November 2019. Figure 9a counts comments in all subreddits; Figure 9b counts comments in coronavirus-related subreddits; Figure 9c counts comments in non-coronavirus subreddits. Increase rates shown in titles are measured among “All” users. Increase rate does not apply to Figure 9b since coronavirus-related subreddits do not exist before the pandemic. The correlation is measured between /r/China_flu-only users and /r/Coronavirus-only users. We also mark two important weeks in the figure: the first week of January 27th, the first week of the outbreak, and the week of March 9th, when WHO declared COVID-19 a pandemic.
| Week       | Increase Rate | Correlation |
|------------|---------------|-------------|
| 01/04      | -22%          | 0.62        |
| 01/04      | -44%          | 0.97        |
| 01/04      | 10%           | 0.13        |
| 01/11      | -18%          | 0.89        |
| 01/18      | 37%           | 0.81        |
| 02/02      | -2%           | -0.30       |
| 02/09      | 247%          | 0.84        |
| 02/16      | 12%           | 0.50        |
| 02/23      | -2%           | -0.30       |
| 03/02      | -1%           | -0.30       |
| 03/09      | -18%          | 0.89        |
| 04/06      | -1%           | -0.30       |
| 04/13      | -1%           | -0.30       |
| 04/20      | -1%           | -0.30       |

Fig. 10. The weekly average number of comments in different categories of subreddits for three groups of users. Increase rates shown in titles are measured among "All" users. The correlation (Corr) is measured between /r/China_flu-only users and /r/Coronavirus-only users. We also mark two important weeks in the figure: the first week of January 27th, the first week of the outbreak, and the week of March 9th, when WHO declared COVID-19 a pandemic.

Technology subreddits (Figure 10h). The increase rate is -12% for /r/China_flu-only users and 11% for /r/Coronavirus-only users. Surprisingly, user activity in the TV/Movies subreddits is decreasing during the pandemic. According to Forbes, streaming hits have jumped by at least 12% in March [9]. This surge does not seem to translate to activity in the TV/Movies subreddits. One possible explanation is that people are more likely to discuss newly released TV series or movies on Reddit. For example, in Figure 10i, the peak around the week of December 16th is mainly due to the release of the classic movie "Star Wars: The Rise of Skywalker". During the pandemic, new film releases have been delayed to future dates or indefinitely [69]. People may spend more time watching old TV series or movies, but are not passionate about discussing them on the Internet.
CONCLUDING DISCUSSION

In this work, we provide a large-scale characterization of Reddit users’ responses to the COVID-19 pandemic. We focus on two “new” communities that emerged on the Reddit platform, /r/China_flu and /r/Coronavirus. By comparing users’ activity and language usage in these two communities from the beginning of the outbreak to late May, we observe an increasing difference between them in many aspects. For example, the language distance between these two communities is going up week by week. The users in /r/China_flu care more about China-related topics, generate more racist comments, and are more likely to be active in other extreme communities. Intriguingly, the February 17th announcement made by the Reddit platform, which makes /r/Coronavirus the official community for COVID-19 and increases moderation effort in /r/Coronavirus, might be associated with this difference. Moreover, we illustrate how the disease is rippling through society by examining users’ activity change on the entire Reddit platform. We find significant activity changes outside COVID-related communities. In some categories, such as finance and food, user activity has recovered to the pre-pandemic level in late April and May as countries reopen, but other categories remain highly impacted.

Implications for moderation practice. Should social media be neutral? This question has drawn increasing attention in our society amidst concerns over bad behavior on the Internet, such as spreading misinformation, supporting conspiracy theories, and promoting racism. One popular argument for non-intervention on social media is to protect freedom of speech. Recently, U.S. President Donald Trump signed an executive order targeting social media censorship. Trump described the move as to “defend free speech from one of the gravest dangers it has faced in American history” [2]. However, allowing totally free and uncensored discussions in online platforms may not work. For example, the well-known unregulated website 4chan.org is responsible for some of the largest hoaxes, conspiracy theories, cyberbullying incidents, and Internet pranks of the past five years [42, 52, 64]. NPR, CNN, Reuters, and other news sites have eliminated their online comment section due to the inability to limit inappropriate content [34]. Subreddit /r/worldpolitics is overwhelmed with NSFW posts featuring porn pictures due to a lack of moderation [13].

The fight against coronavirus on social media notably demonstrates the importance of content moderation on the Internet. Facebook, Twitter, and other service providers have been increasingly active, building ways of removing damaging coronavirus misinformation [19, 26]. The results in our work suggest that /r/China_flu, which has adopted a loose moderation practice, has more racist behavior and a higher overlap with /r/conspiracy. Another coronavirus-related subreddit, /r/Wuhan_Flu, which calls itself the best place for uncensored coronavirus discussion, was quarantined only four days after its creation. Reddit explains that the quarantine decision was made to contain misinformation or hoax content. In summary, considering the potentially harmful impact that low-quality content can have on society during the crisis, social media platforms should take responsibility and play a substantial role in content moderation and curation. It remains an open question as to what kind of moderation is appropriate and effective.

Implications for online extremism. Is the human crisis a golden opportunity for extreme online spaces to grow and recruit new members? Since the beginning of the outbreak, wild conspiracy theories and misinformation began sprouting online [41]. Take /r/conspiracy as an example, its user activity skyrocketed during the COVID-19 pandemic (Figure 12). We find that /r/China_flu, a community dedicated to COVID-related discussions, is attracting users from extreme communities. At the same time, it may serve as a pathway for radical communities to surface and develop. Some users, who are not interested in conspiracy stories or are not aware of such online spaces, in the beginning, may be exposed and become new fans during the pandemic. Future research towards
painting a comprehensive picture of user radicalization on social media platforms during crises is necessary for answering this question.

**Implications for understanding online communities.** Our work demonstrates that online communities do not only exist in the virtual world. User activity in online communities can be heavily embedded in the offline context. COVID-related subreddits provide a unique opportunity for understanding the connections between the online and offline world because these communities only exist as a result of the COVID-19 pandemic. Many activity changes identified in these communities are highly correlated with the timelines of how the pandemic has unfolded in the real world. Such observations emphasize the necessity of connecting online and offline data resources to explain the dynamics of online communities and their relationships with on-going offline events. Our results on user activity outside COVID-related communities also point to possible directions in informing offline policies using online behavior. Further research is required to bridge the gap between the online and offline worlds.

**Limitations**

The findings in our work are subject to several limitations. First, the causal relationship between moderation practices and differences between /r/China_flu and /r/Coronavirus is not established. Due to the nature of our observational study, we do not know what will happen to /r/China_flu if Reddit implements stricter rules. An important confounding factor could be that all the differences are driven by the decision of making /r/Coronavirus the official coronavirus subreddit on the entire platform, not by moderation. However, this factor alone cannot explain the high overlap between /r/China_flu and extreme communities.

Second, most of the data has been collected during the COVID-19 pandemic, a unique period in human history. The results reported in this study are highly connected to this context. For example, there is a steep rise in the expression of anti-Asian bias and blatant harassment across the globe related to fear amidst the epidemic [27, 66]. False information has led to scapegoating and disrespect aimed at persons of Asian descent, particularly those of Chinese origin [52]. This background partially explains the Sinophobic behavior observed in /r/China_flu. The generalization of insights from this work to other contexts requires further investigation.

**ACKNOWLEDGMENTS**

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Fig. 11. The genealogy graph of COVID-related communities on Reddit based on the post activity.

Table 5. A random sample of responses to moderators in /r/China_flu and /r/Coronavirus

| Sample comments                                                                 |
|--------------------------------------------------------------------------------|
| **/r/China_flu**                                                                |
| 1. They have a history of shitty containment... https://www.washingtonpost.com/news-analysis/sars-escaped-beijing-lab-twice-50137? As I said. Shut down their labs, they obviously don’t know what they’re dealing with. |
| 2. Pardon? Do you know who Alois Schickgruber was? My comment is nothing more than a light-hearted take on the famous philosophical question: If you had a time machine, would it be moral to kill the baby Hitler? |
| 3. F*** you. This sub is nothing more than a fake news outlet. Pound sand, nerd. |
| 4. Where did I say it was a bio weapon? Please highlight in my comment where I said that 5. it’s not racism, it’s true. lol. if you’re going to be /r/Coronavirus, what’s the fucking point of this sub. |
| **/r/Coronavirus**                                                             |
| 1. What was infactual about it?                                               |
| 2. So what is speculative? You realize that this speech suppression will be prosecuted, right? You are all entering dangerous territory in suppressing information about COVID 19. This is unprecedented. |
| 3. At least you made...$0.00 for all of your work!                            |
| 4. How in the world was that political? He’s not a politician.                |
| 5. Haha! Give me a break! Imagine being an internet janitor                   |

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APPENDIX

Received TBD 2020; revised TBD 2020; accepted TBD
Table 6. Most upvoted comments in /r/China_flu and /r/Coronavirus

| Score | Comment |
|-------|---------|
| 1610 | 1. Italian here, everything is true. It is bad. STAY HOME!!!!!! |
| 1515 | 2. Next time, you coughed harder, and state “I’m not locked in here with you. You’re locked in here with me” and cough even harder to assert dominance. |
| 1508 | 3. If I can only have one China, I choose Taiwan. |
| 1488 | 4. Wish I hadn’t, I’m fucking exhausted from it. |
| 1416 | 5. The funny thing people who followed this since January on reddit knew all of this two months ago. Next thing you know you know, most don’t develop immunity to the virus. |

| Score | Comment |
|-------|---------|
| 22963 | 1. Just like the simulations |
| 18260 | 2. Strong immune system, better than anyone they tell me. The best. |
| 17183 | 3. Peter told the college students that they were no longer able to stay with the family as originally planned because he couldn’t risk Matt’s grandparents getting exposed to COVID-19 or any other potential germs the group may have encountered. He gets his COVID-19 information right. It’s a correct decision. |
| 16914 | 4. A reminder to all that he’ll be 80 this year, and is well beyond retirement age. He doesn’t have to be doing what he’s doing for us. |
| 16034 | 5. “I do not feel obliged to believe that the same God who has endowed us with sense, reason, and intellect has intended us to forgo their use.” - Galileo Galilei, Letter to the Grand Duchess Christina |

(a) Weekly number of posts in /r/conspiracy.  
(b) Weekly number of comments in /r/conspiracy.

Fig. 12. The weekly number of posts/comments in /r/conspiracy. There is a surge of user activity starting from the week of March 9th, when WHO declared COVID-19 a pandemic [63].