YouTube as a source of information about unproven drugs for Covid-19: The role of the mainstream media and recommendation algorithms in promoting misinformation

Felipe Bonow Soares¹

Igor Salgueiro²

Carolina Bonoto³

Otávio Vinhas⁴

Abstract

In this study, we address how YouTube videos promote misinformation about the unproven drugs for Covid-19 hydroxychloroquine and chloroquine in Brazil. Furthermore, we explore how YouTube's recommendation system might fuel information crises. We follow two research questions. RQ1: How is pro-hydroxychloroquine content propagated on YouTube? RQ2: How does YouTube's recommendation system suggest videos about hydroxychloroquine on the platform? We use mixed methods to explore a dataset of 751 videos collected via the YouTube API v3. We use content analysis to categorize the videos according to the content and the type of channel. We use social network analysis to explore a network based on YouTube's recommendation of videos. We found that the majority of pro-HCQ YouTube videos in our dataset are posted by the mainstream media, most of which reproduce content from free-to-air television channels (RQ1). We also identified a tendency of homophily in the recommendations among pro-HCQ videos and that YouTube was more likely to recommend pro-HCQ videos than anti-HCQ videos (RQ2). The main contribution of our study is the identification of how the Brazilian mainstream media and YouTube's algorithms fueled the spread of pro-HCQ content.

Keywords: Covid-19, Echo Chambers, Recommendation Algorithms, Misinformation, YouTube

¹ PhD in Communication and Information (UFRGS). Researcher at MIDIARS (Media, Discourse and Social Network Analysis) Research Lab. fbonowsoares@gmail.com.

² Undergraduate student in Journalism (UFPEL). Researcher at MIDIARS (Media, Discourse and Social Network Analysis) Research Lab. igorsalgueiro4@gmail.com.

³ PhD student in Communication (UFRGS). Researcher at MIDIARS (Media, Discourse and Social Network Analysis) Research Lab. c.bonoto@gmail.com.

⁴ PhD student in Information and Communication (UCD). Researcher at MIDIARS (Media, Discourse and Social Network Analysis) Research Lab. otavio.vinhas@gmail.com.

Introduction

YouTube is a very popular platform worldwide, however, it is often used for promoting misleading information about health (Madathil et al., 2015). YouTube has over 2 billion monthly logged-in users who access the platform from more than 100 countries⁵. In Brazil, over three-quarters of the population regularly access YouTube, with more than half of this audience focusing on news consumption (Newman et al., 2020). In the context of the Covid-19 pandemic, Brazilian YouTube channels have been spreading misinformation to claim the virus was not a threat, promote conspiracy theories and criticize social distancing and other preventative measures (Machado et al., 2020). Due to the popularity of YouTube, videos containing misleading information about Covid-19 represent a problem for reducing the spread of the virus, as they fuel the so-called “infodemic” (Tangcharoensathien et al., 2020).

In this study, we look at YouTube videos about hydroxychloroquine and chloroquine in Brazil. Although these drugs are not recommended as a treatment or prophylaxis for Covid-19⁶, Brazilian President Jair Bolsonaro and many of his supporters have been promoting hydroxychloroquine and chloroquine as a “cure” and prophylaxis for Covid-19 (Araujo & Oliveira, 2020; Soares et al., 2020; Casarões & Magalhães, 2021). Therefore, we aim to analyze videos about hydroxy/chloroquine on YouTube, in particular, videos that reproduce content promoting the drugs; and explore how YouTube’s recommendation algorithm might contribute to the emergence of echo chambers. We use content analysis and social network analysis to explore a dataset of 751 videos collected via the YouTube API v3 (Rieder, 2015).

Misinformation, Covid-19 and hydroxychloroquine

For the scope of this paper, we use the concept of misinformation to define false, distorted, or inaccurate information that is likely to create biased conclusions and misperceptions (Fetzer, 2004; Floridi, 2011; Flynn et al., 2017). We decided to use misinformation instead of disinformation because the difference between the two concepts is the *intentionality* (Jack, 2017; Benkler et al., 2018; Wardle, 2019), and for this study, it does not matter whether the videos we analyze intentionally or not spread misleading information about the use of hydroxychloroquine as treatment of prophylaxis for Covid-19.

⁵ <https://blog.youtube/press/>.

⁶ [https://www.who.int/news-room/q-a-detail/coronavirus-disease-\(covid-19\)-hydroxychloroquine](https://www.who.int/news-room/q-a-detail/coronavirus-disease-(covid-19)-hydroxychloroquine).

Misinformation about Covid-19 is a global problem, as part of what the World Health Organization defined as “infodemic” (Tangcharoensathien et al., 2020). In particular, misinformation might have had a central role in the spread of the virus in Brazil, as the Federal Government and President Jair Bolsonaro often reproduced misleading claims about the pandemic (Ricard & Medeiros, 2020; Soares et al., 2020; Watmough, 2021). Bolsonaro claimed that Covid-19 was just a “little flu”⁷, often railed against masks⁸, used a homophobic slur to mock masks⁹, removed his mask when he was coronavirus-infected¹⁰, opposed social distancing¹¹, defined as “tyrants” governors and mayors who imposed lockdowns¹², and blamed the media for the crisis¹³.

Bolsonaro and his supporters have also regularly promoted unproven drugs to fight Covid-19¹⁴. In particular, they claimed that hydroxychloroquine and chloroquine should be used as treatment and prophylaxis for Covid-19, which reverberated on social media (Araujo & Oliveira, 2020; Recuero et al., 2021; Casarões & Magalhães, 2021). Bolsonaro himself promoted the use of hydroxychloroquine for Covid-19 in his personal profiles on Facebook (Soares et al., 2021), Instagram (Soares et al., 2020), and Twitter (Spagnuolo & Orrico, 2020), generating millions of interactions and increasing interest in the topic.

In this context, the Brazilian Ministry of Health used emergency public resources to produce four million chloroquine tablets¹⁵, which was considered irregular by the Federal Accounts Court. The Brazilian Senate created a Parliamentary Inquiry Commission to investigate the irregularities in the production and promotion of unproven drugs¹⁶ and other illegal actions of the Bolsonaro’s government during the pandemic. The investigation identified that pharmaceutical companies paid politicians to promote

⁷ <https://edition.cnn.com/2020/05/23/americas/brazil-coronavirus-hospitals-intl/index.html>.

⁸ <https://www.nytimes.com/2021/02/26/world/Bolsonaro-face-masks.html>.

⁹ <https://www.theguardian.com/world/2020/jul/08/bolsonaro-masks-slur-brazil-coronavirus>.

¹⁰ <https://www.bbc.com/news/av/world-latin-america-53328739>.

¹¹ <https://www.reuters.com/article/us-health-coronavirus-brazil-cases-idUSKBN2B92ZA>.

¹² <https://www.bbc.com/news/world-latin-america-56479614>.

¹³ <https://www.theguardian.com/world/2020/mar/23/brazils-jair-bolsonaro-says-coronavirus-crisis-is-a-media-trick>.

¹⁴ <https://edition.cnn.com/2021/02/14/americas/brazil-hydroxychloroquine-evidence-intl/index.html>.

¹⁵ <https://www1.folha.uol.com.br/internacional/en/scienceandhealth/2021/02/nobody-is-doing-anything-wrong-says-bolsonaro-about-brazils-chloroquine-production.shtml>.

¹⁶ <https://www12.senado.leg.br/noticias/materias/2021/06/11/cpi-da-pandemia-comeca-a-investigar-defensores-da-cloroquina>.

unproven drugs¹⁷ and doctors to prescribe them¹⁸, which highly increased the volume of sales of these drugs¹⁹.

Political authorities, activists, and right-wing alternative media fueled the pro-hydroxychloroquine propaganda on social media (Araujo & Oliveira, 2020; Soares et al., 2020; Recuero et al., 2021). Besides, the mainstream media might have helped to promote misleading information about the topic (Tsfati et al., 2020), as it became a trend in the country and previous studies found out that the Brazilian mainstream media play a role in spreading misinformation about Covid-19 by merely reproducing false claims from politicians and using clickbait in headlines (Barbosa et al., 2021; Soares & Recuero, 2021). In this context, 18% of Brazilians believed hydroxychloroquine was a cure for Covid-19 as of July 2020²⁰, and several doctors prescribed the drug for people with positive tests²¹. Based on this scenario, we look at videos about hydroxychloroquine and chloroquine on YouTube, in particular those that contain misleading content.

YouTube, recommendation system, and echo chambers

Many YouTube channels are the source of false, distorted, or inaccurate information about health (Madathil et al., 2015). This is an issue in the context of the Covid-19 pandemic, as videos containing misinformation might fuel the infodemic (Tangcharoensathien et al., 2020). In particular, YouTube's recommendation system is often criticized, as it might create "rabbit holes" and fuel an information crisis by leading users from one video to another despite how problematic the content of the videos might be (O'Callaghan et al., 2014; Mozilla, 2019). The YouTube Team (2019) has already recognized this issue and said they have been working on solutions to improve recommendation algorithms and reduce the spread of harmful content. This is rather important because the recommendation system is a major driver of views on YouTube (Zhou et al., 2016). Besides recommended videos, the results of another study indicate that the consumption of political content on YouTube is driven by a combination of

¹⁷ <https://istoe.com.br/cpi-investiga-o-lobby-da-cloroquina/>.

¹⁸ <https://gauchazh.clicrbs.com.br/politica/noticia/2021/08/senador-aponta-pagamentos-de-empresa-a-medicos-para-incentivar-tratamento-precoce-cks7njbgtg000z01ebgyd3cf2f.html>.

¹⁹ <https://www1.folha.uol.com.br/poder/2021/06/incentivada-por-bolsonaro-principal-fabricante-de-cloroquina-diz-a-cpi-da-covid-que-vendas-subiram-30.shtml> and <https://gauchazh.clicrbs.com.br/politica/noticia/2021/08/a-cpi-diretor-de-farmaceutica-confirma-patrocinio-de-anuncios-e-aumento-de-600-na-venda-de-ivermectina-cks7ybbrk00cd013b4d60jnk5.html>.

²⁰ <https://brazilian.report/liveblog/coronavirus/2020/07/21/18-of-brazilians-believe-hydroxychloroquine-cures-covid-19/>.

²¹ https://www.washingtonpost.com/world/the_americas/coronavirus-brazil-covid-kit/2021/02/12/8328f56a-6632-11eb-8468-21bc48f07fe5_story.html.

several factors, including personal preferences and the influence of content shared on the broader web (Hosseinmardi et al., 2021).

Many studies found evidence that recommendations from YouTube tend to follow homophily as the algorithms tend to suggest similar content, particularly favoring far-right and radical videos and channels (O'Callaghan et al., 2014; Kaiser & Rauchfleisch, 2020; Röchert et al., 2020). It might ultimately lead to the filter bubble phenomenon (Pariser, 2011), as the algorithms tend to follow homophily patterns and suggest more like-minded content; and to the formation of echo chambers (Sunstein, 2001), as the platform might turn into a space that provides videos for users to reinforce their beliefs and potentially become more radicalized.

There are signs of improvement in YouTube's fight against misinformation, as they acted to reduce anti-vaccine content²², for example. The comparison between two studies about anti-vaccine content using the same methods shows that anti-vaccine videos reduced from 65% in 2016 (Song & Gruz, 2017) to 20% in 2019 (Abul-Fottouh et al., 2020). Nevertheless, anti-vaccine videos remained more likely to suggest other anti-vaccine videos (Abul-Fottouh et al., 2020), which indicates that the recommendation algorithm continues following homophily patterns even for harmful content. Besides, many anti-vaccine channels are still on in Brazil and have videos being monetized on the platform (Tokojima Machado et al., 2020).

YouTube has also made an effort to reduce misinformation about hydroxychloroquine and chloroquine. In April 2021, YouTube announced that they removed videos about unproven drugs for Covid-19 that violated YouTube's content policies²³. Nevertheless, previous studies identified a key role of the mainstream media in amplifying misinformation about unproven drugs for Covid-19 on YouTube, for example, in videos containing interviews with doctors who defended hydroxychloroquine, chloroquine, and other unproven medicines (Ramos et al., 2020; Barbosa et al., 2021). YouTube's action to remove pro-hydroxychloroquine content in Brazil estimates the relevance of this topic in the country. This is precisely the reason why we decided to analyze videos about hydroxychloroquine and chloroquine.

²² <https://www.buzzfeednews.com/article/carolineodonovan/youtube-just-demonetized-anti-vax-channels>.

²³ <https://www.cnnbrasil.com.br/tecnologia/2021/04/16/youtube-remove-videos-que-indicam-o-uso-de-cloroquina-e-ivermectina-contr-covid>

Research questions and hypothesis

To understand the influence of YouTube's information ecosystem in the spread of misleading information about unproven drugs in Brazil, we explore pro-hydroxy/chloroquine (HCQ) is produced in YouTube videos and the role of YouTube's recommendation system in promoting this type of content. Therefore, two research questions guide the analysis of this study.

RQ1: How is pro-hydroxychloroquine content propagated on YouTube?

In RQ1, we aim to understand how misleading content about unproven drugs spread on YouTube videos. In particular, we aim to explore the role of different types of YouTube channels in promoting hydroxy/chloroquine. Besides, we seek to compare how users interact with pro-HCQ and anti-HCQ videos. Based on this discussion, we propose the following hypotheses:

H1a: Most pro-HCQ videos in our dataset are from mainstream media channels. Previous studies that focused on smaller samples of videos about unproven drugs found out that the mainstream media sometimes reverberated misleading content (Ramos et al., 2020; Barbosa et al., 2021). Besides, YouTube has been acting to reduce the amount of misinformation on the platform (YouTube Team, 2019). As data collection was made through YouTube API v3, which is based on YouTube's search algorithms and recommendation system, we may expect that the recommendation algorithms might favor more credible channels.

H1b: Videos containing pro-HCQ content generate more views and interactions (likes, dislikes, comments) compared to anti-HCQ videos. Previous research found out that groups engaged in spreading misinformation are often more active (Benkler et al., 2018), including in the discussion about unproven drugs for Covid-19 on other social media platforms (Recuero et al., 2021; Soares et al., 2021). Therefore, we expect that pro-HCQ videos generate more engagement on YouTube.

We also aim to further explore one particular metadata of our dataset: the list of recommended videos. Thus, our second research question is as follows:

RQ2: How does YouTube's recommendation system suggest videos about hydroxychloroquine on the platform?

In RQ2, we seek to understand how YouTube's recommendation algorithms might create echo chambers by favoring homophily. In particular, we aim to explore whether the homophily effect is stronger for pro-HCQ videos compared to anti-HCQ videos. Thus, we propose two hypotheses:

H2a: YouTube's suggestions follow homophily, possibly fueling the echo chamber effect. That is, pro-HCQ videos are more likely to suggest other pro-HCQ videos, while anti-HCQ videos are more likely to suggest other anti-HCQ videos. As many studies identified, YouTube's recommendation system tends to suggest similar content, even in videos containing misleading content (Abul-Fottouh et al., 2020; Kaiser & Rauchfleisch, 2020).

H2b: The homophily effect is stronger among pro-HCQ videos. As previous researchers identified, the homophily of YouTube recommendations is particularly strong for radicalized and misleading videos (O'Callaghan et al., 2014; Röchert et al., 2020). Thus, we expect to find a stronger echo chamber effect for videos containing pro-HCQ content.

Methods

We used YouTube Data Tools (Rieder, 2015) to collect videos via the YouTube API v3. We used the Video Network Module to retrieve YouTube videos and recommended videos. The search query we used to collect videos was “*hidroxicloroquina*” OR “*cloroquina*” (hydroxychloroquine and chloroquine in Portuguese, respectively). We included a language filter, to retrieve videos in Portuguese. This initial search created a seed list of 500 videos. YouTube API v3 provides the seed list based on relevance, that is, these videos were ranked by YouTube as most relevant based on our search query. We also collected the recommended videos (up to 50) for each of the videos in the seed list (crawl depth: 1). YouTube API v3 provides metadata for all collected videos. Data collection was made on March 16, 2021, approximately one year after Bolsonaro started promoting hydroxychloroquine in Brazil.

The resulting dataset contained 11,779 videos. However, most of these videos were not about the unproven drugs for Covid-19 that we are focusing on in the analysis.

Therefore, we excluded videos which titles did not include the words we used in the search query. We also identified 25 videos in Spanish, nevertheless, we decided to keep these videos in our final dataset because they are linked to videos in Portuguese in the video network based on recommended videos on YouTube. The final dataset comprises 751 videos.

We used mixed methods to explore the dataset. To answer RQ1, we used content analysis (Bardin, 1977) to categorize the videos according to the content, and the channel. To classify the content of each video, we created three categories: pro-HCQ, anti-HCQ, and without a clear position. Table 1 provides a breakdown of how we considered each of these categories.

Table 1. Video content categories framework

Category	Description
Pro-HCQ	We consider that a video contains pro-HCQ content when it reproduces claims that the drugs are a cure or prophylaxis for Covid-19, reproduces an interview with someone promoting the drugs, includes stories of people allegedly cured by HCQ, and/or incentivizes people to use the drugs by reverberating protocols from the Brazilian Federal Government or any hospital without mentioning that the drugs do not have efficacy as a treatment for Covid-19.
Anti-HCQ	We consider that a video contains anti-HCQ content when it reverberates studies that found no evidence of the efficacy of the drugs for Covid-19, reproduces instructions from medical authorities to not use the unproven drugs, includes an interview with someone defending that hydroxy/chloroquine are unproven drugs for Covid-19, and/or clearly mention that despite that some people promote hydroxy/chloroquine, the drugs do not have efficacy for treating Covid-19.
Without a clear position	We consider that a video has no clear position when it does not directly associate the drugs with Covid-19, or it does not clearly contain pro-HCQ nor anti-HCQ content.

To classify the YouTube channels, we considered six categories. These categories emerged from a pre-analysis of the data (Bardin, 1977). To classify each channel, we considered its name, description, and videos. We describe each category in Table 2.

Table 2. YouTube channel categories framework

Category	Description
Mainstream media	YouTube channels from free-to-air television channels, cable television channels, daily newspapers, radio stations, traditional online news portals, and mainstream media in general.
Alternative media	YouTube channels from alternative sources of information, such as hyperpartisan media, independent media, and other types of non-traditional news outlets.
Political	YouTube channels which the main topic is politics, such as channels from politicians, activists, political analysts, and journalists covering political issues.
Entertainment	YouTube channels which the main topic is entertainment. For example, music, humor, cinema, etc.
Science, health, and education	YouTube channels from organizations associated with research, health, and/or education in general, or YouTube channels which the main topic is science, health, and/or education.
Other	YouTube channels that cannot be classified as any other categories.

Three independent coders classified the data. The coding was performed by the authors of this study for better accuracy and to allow us to have more in-depth insights into our data. Each of the coders watched all the 751 videos to classify the content and the channel following the framework presented above. To ensure the reliability of the coding, we calculated Cohen's Kappa. Table 3 provides detailed information about the interrater agreement. We reached a substantial agreement for the content of the videos and an almost perfect agreement for the channels (Cohen, 1960; Landis & Koch, 1977).

Table 3. Information about interrater agreement

Coders	Content	Channel
Coders 1 and 2	$\kappa = .73$	$\kappa = .901$
Coders 1 and 3	$\kappa = .746$	$\kappa = .931$
Coders 2 and 3	$\kappa = .774$	$\kappa = .921$
Overall	$\kappa = .75$	$\kappa = .917$

We considered the agreement between at least two coders for the final classification. There were disagreements between the three coders about the content of six videos. We decided to classify the content of these videos as without a clear position for the final classification.

We used statistical tests to explore the metadata of the videos provided by YouTube's API. We tested the data (views, comments, likes, dislikes) for normality and homogeneity of variance and identified that neither could be assumed. Besides, sample sizes were not equal. Therefore, we used Welch's t-test to correct these violations (Zimmerman, 2004). We used Welch's t-test to test for statistical differences in means of the metadata from anti-HCQ and pro-HCQ videos. There were missing values in some videos, therefore we did not consider these videos in the tests. We used JASP (JASP Team, 2020) to perform the statistical tests and create the descriptive plots presented in this paper.

To answer RQ2, we relied on social network analysis (Wasserman & Faust, 1994). We used the Video Network Module to collect videos via YouTube Data Tolls (Rieder, 2015). Thus, we retrieved a network of recommended videos, in which nodes are YouTube videos and edges represent YouTube's recommendation of videos. Based on the content analysis, we focused on two metrics to analyze how YouTube's recommendation algorithm might fuel the emergence of echo chambers.

We used E-I index to compare the connections within groups and between groups (Krackhardt and Stern, 1988). Usually, E-I index ignores the direction of ties. However, as we are looking at recommended videos, we only considered ties that nodes send in the network. That is, we only look at which videos are recommended by each video in the network, based on the content of the videos (content analysis) to define whether a tie is internal or external. E-I index ranges from -1 (all ties are internal to the group) to +1 (all ties are external to the group). Therefore, a negative index indicates that connections

within groups are more frequent than connections between groups, while a positive index indicates the opposite.

We also used clustering coefficient (Watts & Strogatz, 1998) to explore the tendency of nodes from each group cluster together. The clustering coefficient metric measures how close are the neighbors of a particular node, that is, how interconnected are the connections of a node. The average clustering coefficient of groups provides information about the density of the connections within the group. In the case of our analysis, this is helpful to further explore the likelihood of someone who watches a pro-HCQ video, for example, to continue watching more and more pro-HCQ videos – the echo chamber (Sunstein, 2001) or “rabbit hole” (O’Callaghan et al., 2014) effect.

Finally, we used once again Welch’s t-test to compare mean indegree from anti-HCQ and pro-HCQ videos. We used indegree because this metric is related to how often videos from our dataset were recommended by YouTube when a user watched other videos from our dataset. This test was used to understand how YouTube’s recommendation system could be favoring videos with a particular type of content in the debate about unproven drugs.

Results

Our first research question focused on the content of the videos in our dataset, particularly those promoting hydroxychloroquine. Out of the 751 videos we analyzed, most contained anti-HCQ content (368 – 49%), closely followed by pro-HCQ videos (323 – 43%). Videos without a clear position about the use of hydroxychloroquine as a treatment or prophylaxis for Covid-19 were the minority in our dataset (60 – 8%). Figure 1 provides a breakdown of the categories we analyzed (content and type of channel).

Figure 1. Type of content per type of channel

As described in Figure 1, videos from the mainstream media were the majority in all types of content. Mainstream media account for 72% of the videos containing pro-HCQ content and 52% of anti-HCQ videos. Videos from alternative media channels and science, health and education channels more often contained anti-HCQ content, frequently reverberating scientific tests with the drugs.

Many of the mainstream media videos containing pro-HCQ content are from Brazilian free-to-air television channels. These videos reproduce parts of programs broadcasted by these free-to-air television channels. Other mainstream media videos containing pro-HCQ content often reproduce part of speeches, Facebook lives, or interviews from Bolsonaro, in which he promotes the use of hydroxychloroquine. In these videos, there are no mentions of reliable sources that consider hydroxychloroquine and chloroquine unproven drugs for Covid-19.

These findings support our Hypothesis 1a: *Most pro-HCQ videos in our dataset are from mainstream media channels*. This result points to the role of mainstream media in amplifying misinformation (Tsfati et al., 2020) by posting YouTube videos containing pro-HCQ content. This result is also in line with previous analysis that also found out that the Brazilian mainstream media played a role in promoting unproven drugs (Ramos et al., 2020; Barbosa et al., 2021). Likely, this result was also influenced by how we collected the data. We used YouTube's API that provides videos based on YouTube's search system. Therefore, videos from mainstream media might be more likely to be suggested in searches on YouTube. Nevertheless, we consider this finding relevant because it points to the role of mainstream media in fueling misinformation about unproven drugs.

We used videos metadata provided by YouTube's API to explore how different were the numbers of views and interactions between pro-HCQ and anti-HCQ videos. We compared four elements: views, comments, likes, dislikes. As explained in the methods section, we used Welch's t-test to correct violations of normality and homogeneity of variance (Zimmerman, 2004). Figures 2 and 3 illustrate the distribution of views and likes. For the former, there were 39 pro-HCQ outliers and 41 anti-HCQ outliers. For the latter, there were 53 pro-HCQ outliers and 48 anti-HCQ outliers.

We found statistical significant differences for views, *Welch's* $t(655.85) = 3.256$, $p = .001$, 95% CI [0.1, 0.4]; comments, *Welch's* $t(596.43) = 3.031$, $p = .003$, 95% CI [0.08, 0.39]; and likes, *Welch's* $t(526.5) = 2.468$, $p = .014$, 95% CI [0.04, 0.34]. Pro-HCQ videos had higher means for all these metadata. On the other hand, Anti-HCQ videos received more dislikes, but the difference was not statistically significant, *Welch's* $t(542.7) = -1.872$, $p = .062$, 95% CI [-0.29, 0.01]. Table 4 and Figures 4-7 provide more information about the tests.

Table 4. Views and interactions in pro-HCQ and anti-HCQ videos

Metadata	Content	N	Mean	SD
Views	Pro-HCQ	323	61854.94	111381.88
	Anti-HCQ	368	35345.17	101270.11
Comments	Pro-HCQ	321	469.22	760.80
	Anti-HCQ	346	309.64	578.81
Likes	Pro-HCQ	319	4732.07	11971.50
	Anti-HCQ	367	2806.09	7656.61
Dislikes	Pro-HCQ	319	131.10	214.88
	Anti-HCQ	367	180.21	446.48

We also looked at specific channels that posted both pro-HCQ videos and anti-HCQ videos. This exploratory analysis aimed to further explore whether the larger number of views, comments, and likes for pro-HCQ videos was related to the content of the videos or the consequence of channels with more subscriptions sharing pro-HCQ content. We selected the four channels with the most videos in our dataset among those that posted pro-HCQ and anti-HCQ videos. We compared views and interactions of pro-HCQ and anti-HCQ videos in these four channels using Welch's t-test. Table 5 provides a breakdown of the statistical tests.

In all four channels, pro-HCQ videos received more views compared to anti-HCQ videos, although this result has statistical significance in only two cases. In all the cases, pro-HCQ videos received more likes, all four with statistical significance. In all cases, pro-HCQ videos received more comments, but only in one with statistical significance. Finally, in two cases anti-HCQ videos received more dislikes, none with statistical significance, and in the other two cases, pro-HCQ videos received more dislikes, one with statistical significance. In general, these results, especially those related to views and likes, indicate that pro-HCQ videos tend to receive more views and interactions because

of the content of the video, as we identified relevant differences in videos with different content in the same channel.

Table 5. Comparison of channels that posted both pro-HCQ and anti-HCQ videos

Channel	Variable	Content	N	Mean	SD	Welch's <i>t</i>	df	<i>p</i>
UOL	Views	Pro	40	38123.33	61256.71	2.64	47.15	.011
		Anti	14	11019.79	12814.77			
	Comments	Pro	40	330.83	418.7	0.15	18.51	.880
		Anti	14	306	552.12			
	Dislikes	Pro	40	130.28	165.62	-0.2	17.44	.843
		Anti	14	144.36	242.45			
	Likes	Pro	40	791.68	1489.43	2.16	44.89	.036
		Anti	14	261.93	255.65			
Band Jornalismo	Views	Pro	18	51080.61	71598.9	1.77	27.27	.087
		Anti	17	16402	40794.4			
	Comments	Pro	18	308.61	253.32	0.16	23.85	.873
		Anti	17	287.41	483.98			
	Dislikes	Pro	18	109.72	107.33	0.1	22.29	.919
		Anti	17	103.41	231.48			
	Likes	Pro	18	1340.44	1943.89	2.1	20.3	.048
		Anti	17	331.53	592.17			
Jovem Pan News	Views	Pro	17	76162.29	142222.76	1.96	16.36	.067
		Anti	14	8040.93	13672.26			
	Comments	Pro	17	420.12	833.83	1.26	18.78	.224
		Anti	14	154.57	225.38			
	Dislikes	Pro	17	127.94	168.65	-0.2	23.14	.843
		Anti	14	142.86	233.01			
	Likes	Pro	17	4130.77	7386.77	2.16	16.15	.046
		Anti	14	251.79	457.64			
Jornal da Record	Views	Pro	21	49721.05	87808.18	2.29	20.2	.033
		Anti	6	5833.33	3311.35			
	Comments	Pro	21	259.43	370.51	2.19	24.34	.038
		Anti	6	69	77.89			
	Dislikes	Pro	21	70.91	94.48	2.59	21.75	.017
		Anti	6	16.33	11.02			
	Likes	Pro	21	1891.19	3388.12	2.32	20.21	.031
		Anti	6	172.83	130.9			

These findings mostly support our hypothesis 1b: *Videos containing pro-HCQ content generate more views and interactions (likes, dislikes, comments) compared to anti-HCQ videos*. Interestingly, the only metric that the mean in pro-HCQ videos is not statistically significantly higher than anti-HCQ is dislikes, which can be considered a negative type of interaction. These results indicate that YouTube (and other social media) users that supported the use of hydroxychloroquine and chloroquine for Covid-19 were likely engaged in promoting pro-HCQ videos from our dataset, as they received more

views, likes, and comments. These findings are in line with previous studies that identified that social media users engaged in spreading misinformation are often more active (Benkler et al., 2018), even in discussions about unproven drugs for Covid-19 (Recuero et al., 2021; Soares et al., 2021).

To explore our second research question, we focused on the recommended videos metadata. As detailed in the methods section, we used social network analysis to explore how YouTube's recommendation system could create "echo chambers" by following homophily when suggesting related videos. The network was composed of 751 nodes and 10,116 edges.

We examined three metrics to explore hypotheses 2a and 2b. First, we calculated the E-I index, particularly looking at the connections made by the nodes. That is, we analyzed whether videos recommended other videos containing the same content or different content. We found out that it is more likely that recommended videos in general follow homophily, however, the E-I index was very close to zero (-0.02), which indicates a similar number of internal and external ties. We discovered that pro-HCQ videos were more likely to recommend other pro-HCQ videos. On the other hand, anti-HCQ videos were more likely to create external connections, that is, to recommend pro-HCQ videos and videos without a clear position. Finally, videos without a clear position were also more likely to create external connections, but this result is influenced by the small number of videos in this category – only 8% of our dataset.

We also calculated the average clustering coefficient for the entire network and for each group to explore how interconnected were the videos from our dataset. The results follow the same tendency of the E-I index. The average clustering coefficient of pro-HCQ videos is higher than other groups and the entire network. This indicates higher density within the pro-HCQ group, that is, the neighborhood of videos is more closely interconnected. The average clustering coefficient of anti-HCQ videos and videos without a clear position groups is smaller than the entire network, which indicates a lower tendency of interconnections. Full details of the E-I index and clustering coefficient are provided in Table 6.

These results indicate that pro-HCQ are more likely to create an echo chamber (Sunstein, 2001) effect and lead YouTube users into "rabbit holes" (O'Callaghan et al., 2014). As the recommendation system tends to be a driver of views on YouTube (Zhou et al., 2016), users that watch a video containing pro-HCQ content are more likely to watch other videos promoting unproven drugs for Covid-19.

Table 6. Metrics used to explore homophily and clustering

Group	E-I index	Average clustering coefficient
Anti-HCQ	0.06	0.132
Pro-HCQ	-0.22	0.178
Without a clear position	0.75	0.156
Network	-0.02	0.157

We also decided to explore how often videos from our dataset were recommended by YouTube. In particular, we wanted to understand whether pro-HCQ or anti-HCQ videos were more likely to be recommended. Therefore, we compared indegree means for these two types of videos using Welch's t-test. We identified that YouTube was more likely to recommend pro-HCQ videos in our dataset. The result of the test was statistically significant, *Welch's* $t(579.54) = 2.543$, $p = .011$, 95% CI [0.05, 0.35]. More information about the comparison between the two groups is provided in Table 7 and Figure 8.

Table 7. Indegree of pro-HCQ and anti-HCQ videos

Group	N	Mean	SD
Pro-HCQ	323	16.51	32.05
Anti-HCQ	368	11.03	23.25

Figure 8. Mean number of indegree

As we previously identified that pro-HCQ videos received more views, we decided to further explore how views could have influenced indegree (number of recommendations in our dataset). That is, we wanted to understand if there was a correlation between popularity (number of views) and recommendations on YouTube. Therefore, we calculated the Pearson correlation coefficient to measure the correlation between views and indegree. Although there was a positive correlation, this was weak: *Pearson's* $r(689) = 0.291$, $p < .001$. This indicates that there was some relationship between popularity and recommendations, however, the relationship was unsubstantial to explain why pro-HCQ videos were more recommended in our dataset. Figure 9 provides visual data about the relationship between views and indegree.

Figure 9. Correlation between views and indegree

These findings suggest that pro-HCQ videos are more likely to recommend other pro-HCQ videos and that this tendency is fueled by YouTube's recommendation algorithms. Although pro-HCQ videos were less in number (43%) compared to anti-HCQ videos (49%) in our dataset, pro-HCQ videos were more likely to be recommended on YouTube. Consequently, this finding highlights the role of YouTube in fueling misinformation about unproven drugs for Covid-19.

Our results do not support Hypothesis 2a: *YouTube's suggestions follow homophily, possibly fueling the echo chamber effect*. Although there was a general tendency of homophily, this tendency was very weak and mostly created by pro-HCQ videos. Therefore, our findings support Hypothesis 2b: *The homophily effect is stronger among pro-HCQ videos*. These results are in line with other studies that identified YouTube's algorithms tendency to follow homophily in recommending videos containing misleading content (O'Callaghan et al., 2014; Abul-Fottouh et al., 2020; Kaiser & Rauchfleisch, 2020; Röchert et al., 2020).

Discussion

Based on the results of our analysis, we identified that the Brazilian mainstream media and YouTube played key roles in promoting unproven drugs for Covid-19 in Brazil. As we explored in our first research question, most videos containing pro-HCQ content were posted by mainstream media channels. An important note is that many of these videos contain parts of programs broadcasted by free-to-air television channels, which indicates the existence of a larger ecosystem of misinformation. This is relevant because two-third of Brazilians mentioned TV as a source of news in the Reuters Digital News Report (Newman et al., 2020).

Some of the channels that posted videos containing pro-HCQ videos are associated with some of the most trusted brands in Brazil (Newman et al., 2020), such as Band News (35 pro-HCQ videos and trusted by 76% of Brazilians), Record News (51 videos and 74%), and UOL (40 videos and 66%). Band and Record News are both free-to-air television channels. Many of these videos include journalists or TV hosts that promote hydroxychloroquine and chloroquine, and interviews with politicians and health specialists that defend the unproven drugs. Jovem Pan, the largest radio station in Brazil, also posted 46 videos containing pro-HCQ content. They are similar to the videos posted by Band and Record News, often containing hosts or guests promoting the drugs. UOL is the largest online news portal in Brazil. Videos posted by UOL differ from the others, as many of them simply reproduce parts of speeches, Facebook lives, or interviews from Bolsonaro in which he promotes the unproven drugs. These videos do not contain any corrections over Bolsonaro's false claims or mentions to scientific studies that did not identify any efficacy on the use of these drugs in the treatment for Covid-19.

The role of mainstream media in promoting unproven drugs for Covid-19 is relevant because of how Brazilians trust these sources. The mainstream media might fuel

misinformation spread even when correcting false claims (Tsfati et al., 2020). This turns out to be even more harmful when the mainstream media is actually promoting misleading content. When the mainstream media produces misleading content, social media users often share this content to reinforce misinformation narratives (Soares & Recuero, 2021). The same is potentially true for YouTube videos promoting unproven drugs, which could end up fueling the so-called infodemic (Tangcharoensathien et al., 2020).

Another important factor in the spread of pro-HCQ content on YouTube is the role of users and how they interact with these videos. We identified that videos containing pro-HCQ content received more likes, comments, and views than videos containing anti-HCQ content. These findings suggest that YouTube users were more active in watching and interacting with pro-HCQ videos. Furthermore, these findings might be the result of more activity on other social media platforms and messaging apps. Possibly, these videos were shared in other spaces to promote hydroxychloroquine and chloroquine for Covid-19, which could explain the higher number of views, likes, and comments (and lower number of dislikes).

Finally, we identified that YouTube played a key role in the process. The higher number of views and interactions in pro-HCQ videos might have been partially influenced by how YouTube recommended these videos. We identified that YouTube was more likely to suggest pro-HCQ videos than anti-HCQ videos. Therefore, YouTube's recommendation algorithms end up promoting unproven drugs. On the other hand, we also identified that the correlation between views and indegree was weak. This indicates that the higher number of views in videos containing pro-HCQ content might be the result of personal preferences and the promotion of misleading content on other social media platforms, as suggested by Hosseinmardi et al. (2021).

In addition, we identified that the videos suggested when a user watched a pro-HCQ video followed homophily patterns. This could reinforce the echo chamber (Sunstein, 2001) effect, in which users that watched a video promoting unproven drugs would likely watch more videos promoting these drugs. Therefore, YouTube users could enter into “rabbit holes” of misleading information (O'Callaghan et al., 2014). This is particularly relevant because YouTube's recommendation system might be a major driver of views (Zhou et al., 2016).

YouTube Team (2019) says they have been working to improve recommendation algorithms. This action might explain the large number of videos from mainstream media channels in our dataset. Nevertheless, we identified that YouTube's recommendation

algorithms are contributing to the spread of misleading information, in particular by often suggesting videos containing pro-HCQ content. Another factor that might influence this issue is the language. Most of the videos in our dataset are in Portuguese. YouTube may have been developing ways to improve recommendation algorithms for videos in English, but there are still many flaws for videos in Portuguese – and possibly in other languages as well.

In April 2021, YouTube announced that they removed thousands of videos about unproven drugs. As we collected our dataset in March 2021, we revised it to identify which videos were removed. As of August 6, 2021, only 21 videos were removed because the content violated YouTube’s policies. Most of these videos (20 – 95%) contained pro-HCQ content. As for the type of channel, the majority was posted by mainstream media channels (15 – 71%). Also, 18 videos were unavailable or private, of which 12 (67%) contained pro-HCQ content. The majority of the unavailable or private videos were posted by political channels (13 – 72%). Despite YouTube’s actions to reduce the number of videos promoting unproven drugs on the platform, 90% of the videos containing pro-HCQ content from our dataset are still available. The removed, unavailable or private pro-HCQ videos received over 4 million views by March 2021, when we collected the data. In particular, eight videos posted by Alexandre Garcia, a political commentator and Bolsonaro’s supporter, were unavailable or private – altogether, they accounted for almost 2 million views. This indicates that YouTube’s actions to remove misinformation about unproven drugs had little effect, as most pro-HCQ videos are still online and those that are not available anymore received millions of views before they were removed or made private/unavailable.

Conclusion

In this study, we focused on how YouTube videos contributed to the “infodemic” (Tangcharoensathien et al., 2020). In particular, we looked at videos about hydroxychloroquine and chloroquine, two unproven drugs promoted by Brazilian President Jair Bolsonaro and his supporters. We used mixed methods to explore two research questions. RQ1: How is pro-hydroxychloroquine content propagated on YouTube? RQ2: How does YouTube’s recommendation system suggest videos about hydroxy/chloroquine on the platform?

We identified that Brazilian mainstream media played a key role in promoting these unproven drugs, as the majority of videos containing pro-HCQ content were posted

by mainstream media channels (72%). Many of these videos reproduce content from free-to-air television channels, which suggest the existence of a larger ecosystem of misinformation about unproven drugs for Covid-19 in Brazil. Furthermore, we identified that pro-HCQ videos received more views, likes, and comments, which suggests that YouTube users interacted more with videos promoting the drugs.

We also found out that YouTube's recommendation system favored pro-HCQ content on the platform. We identified that pro-HCQ videos were more likely to recommend other pro-HCQ videos, possibly creating "rabbit holes" (O'Callaghan et al., 2014) and reinforcing an "echo chamber" (Sunstein, 2001) effect. Furthermore, we identified that YouTube's algorithms more often recommended pro-HCQ videos than anti-HCQ videos. Therefore, YouTube ends up promoting pro-HCQ content and fueled the spread of misinformation.

Our study contributes to the field by analyzing non-English videos, as videos in English are the focus of most of the research on health misinformation on YouTube (Abul-Fottouh et al., 2020). The discussion on the roles of the Brazilian mainstream media and YouTube in fueling misinformation about unproven drugs for Covid-19 is another contribution of our study. Although we focused on Brazil, the finding on the role of the mainstream media in amplifying misinformation about unproven drugs is relevant to understand how legitimate actors might be contributing to the Covid-19 infodemic worldwide. Besides, YouTube's algorithms are likely to play a similar role in fueling misinformation spread in other countries as well as we identified in our study. This tendency might be stronger among non-English videos, which is something that future studies can explore.

This study has some limitations. We used YouTube API v3 to collect data. This API uses YouTube's search rank to provide videos based on the search query we used. Therefore, this might have influenced the large number of videos from mainstream media channels. Besides, our sample is not representative of the entirety of YouTube's content and we are unable to measure how many other videos about hydroxychloroquine and chloroquine are available on YouTube. There are also some limitations in the use of the E-I index to measure homophily. Although this metric helped us to identify a tendency of pro-HCQ videos recommending more pro-HCQ videos, the formula used for the calculation of the E-I index is not robust.

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