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The Impact of the Politicization of Health on Online Misinformation and Quality Information on Vaccines

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Abstract

In July 2017, a law aimed at reversing the decline in vaccination cover (Law 119/2017) made child vaccination mandatory in Italy. The law sparked a heated debate which was a breeding ground for disinformation and misinformation but also set the stage for some initiatives that have tried to combat the problem. This paper analyzes the Twitter vaccine-related information environment by focusing on the information sources shared by about 500,000 tweets published within three years – 18 months before and after the promulgation of the Law 119/2017 on mandatory vaccinations – highlighting clusters of sources shared by the users and changes in problematic and quality information throughout that period. Results show that the politicization of the topic was associated with the growing spread of problematic information. They expose the vaccine-related information environment as characterized by an homophilic and polarized structure grouping together and opposing, on the one hand, anti-vaccination, blacklisted sources, alternative therapy and conspiracy websites, and on the other, scientific and health sources, revealing that despite the new initiatives aimed at increasing quality information and fighting problematic information online, there was a lack of scientific information both during and after the debate on the vaccinations law, while problematic information appears to have increased in volume over the years.

Keywords: anti-vaccination movement, social media, health misinformation.

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1. Introduction

Concern over the spread of problematic information on social media has increased in the last few years. Misinformation and disinformation[1] erode trust in public institutions and try to undermine political processes (Giglietto, Righetti, Rossi, Marino, 2020; Lazer et al., 2018; Tucker et al., 2018), posing a danger to public health. Problematic information about vaccines is a case in point. By eroding trust in vaccines (Kata, 2010, 2012) it can impact on vaccine hesitancy (Dube, Vivion, MacDonald, 2015; European Commission, 2018, 2019; WHO, 2019a, 2019b), and even represent a pandemic risk (Larson, 2018).

Italy is facing several issues with both political and scientific problematic information. The Italian authority for communications highlighted that the market share of misinformation has increased dramatically since the end of 2017, and science and technology topics account for about 19% of the overall misinformation market, second only to politics (57%) (AGCOM, 2018). In Italy, political and health misinformation became especially crucial issues in 2017, when a measles outbreak infected thousands of people[2] (Filia et al., 2017; ISS, 2019; WHO, 2019a), and political mis- and disinformation threatened the imminent general election of March 4, 2018 (Fletcher et al. 2018; Giglietto et al., 2018, 2019a, 2020). The so-called "Lorenzin decree" (named after the Italian Minister of Health at the time, Beatrice Lorenzin), aimed at reversing the decline in vaccination uptake observed in the previous few years by introducing mandatory child vaccinations (Chirico, 2018; Signorelli, Odone, Cella, Iannazzo, 2018). The decree became law on July 31, 2017 (Law 119/2017), sparking a heated debate which provided fodder for problematic political and health information on social media and mainstream media (Casula, Toth, 2018; Lovari et al., 2020). At the same time, many initiatives were launched to offset problematic health information and promote scientific, quality information on social media These included "Dottore, ma è vero che…?" ('Doctor is it true

[1] "Misinformation" refers to false information spread unintentionally and "disinformation" to false information spread intentionally (e.g.: Wardle, Derakhshan, 2017). There is an ongoing debate on the terminology and categories used to discuss and untangle the complex problem of so-called "fake news" (e.g.: Farkas, Schou, 2018; Giglietto et al., 2019a; Venturini, 2019). In this paper, the term "problematic information" will be used to refer to all types of false or inaccurate information, in a way similar to the use of the term "pseudo-information" suggested by Kim, de Zúñiga (2020).

[2] Since the beginning of 2013, 13,001 measles cases have been reported in Italy, of which 2,270 in 2013, 1,695 in 2014, 256 in 2015, 861 in 2016, 5,393 in 2017 and 2,526 in 2018 (ISS, 2019).

that…?") (FNOMCeO, 2018), "ISS Salute" ("ISS Health") (ISS, 2018a), and "Medical Facts" (Burioni, 2018).

For all these reasons, Italy provides an interesting perspective on the dynamics of problematic political and health information on social media. Using Twitter, a relevant social media with about 2.35 million monthly active users in Italy (We Are Social, 2019), this paper sheds light on some questions relative to the spread of problematic health information and its relation with the politicization of health, the volume of scientific information circulating online, and the homophilic and polarized structure of the vaccine-related information ecosystem.

2. Research questions

Many studies have focused on vaccine-related information and problematic information on mass media, the Internet, and social media[3]. However, not much research has analyzed the social media vaccine-related debate at a crossroads: responding to a major policy change represented by the Italian law on mandatory vaccinations. Recently, it has been observed that conversations on Twitter increased before the introduction of the Law 119/2017, and anti-vaccination tweets outweighed pro-vaccination ones (Tavoschi et al., 2020), but there is a lack of studies focusing on what happened after the promulgation of the law. This research started by conducting an exploratory analysis aimed at discovering the trend of social media conversations on the topic and the events that triggered them before, during and after the approval of the law:

[3] It would require a separate work to conduct a systematic review of the studies in the field. Without any claim to completeness, the following studies may be mentioned as examples: Ache, Wallace, 2008; Bean, 2011; Betsch, Renkewitz, Betsch, Ulshöfer, 2010; Blankenship et al., 2018; Bodemer, Müller, Okan, Garcia-Retamero, Neumeyer-Gromen, 2012; Clarke, Dixon, Holton, McKeever, 2015; Briones, Nan, Madden, Waks, 2012; Broniatowski et al., 2018; Comunello, Mulargia, Parisi, 2017; Covolo, Ceretti, Passeri, Boletti, Gelatti, 2017; Danovaro-Holliday, Wood, LeBaron, 2002; Dixon Clarke, 2013; Dunn et al., 2017; Donzelli et al., 2018; Ekram, Debiec, Pumper, Moreno, 2019; Fadda, Allam, Schulz, 2015; Ghanbari, Yousefi Nejad, Jafari Navimipour, Hosseinzadeh, 2019; Gollust, Attanasio, Dempsey, Benson, Fowler, 2013; Gollust, LoRusso, Nagler, Fowler, 2016; Habel, Liddon, Stryker, 2009; Hilton, Hunt, Langan, Bedford, Petticrew, 2010; Himelboim, Xiao, Lee, Wang, Borah, 2019; Grant et al., 2015; Kata, 2010, 2012; Lin, Lagoe, 2013; Moran, Lucas, Everhart, Morgan, Prickett, 2016; Skea, Entwistle, Watt, Russell, 2008; Schmidt, Zollo, Scala, Betsch, Quattrociocchi, 2018; Smith, Ellenberg, Bell, Rubin, 2008; Speers, Lewis, 2004; Tafuri et al., 2014; Ward, Peretti-Watel, Larson, Raude, Verger, 2015; Witteman, Zikmund-Fisher, 2012.

RQ1) What was the volume of vaccine-related conversations on Twitter in Italy, and what were the main events that triggered them before, during and after the discussion on the law on mandatory vaccinations?

Studying health and political information on social media can not disregard the fact that social media users tend to gather around like-minded communities, driven by the homophily principle – the tendency of people to interact with similar others (Lazarsfeld, Merton, 1954; McPherson, Smith-Lovin, Cook 2001) – and are considered at risk of ideological segregation and polarization (Dandekar, Goel, Lee, 2013; Pariser, 2011; Samantray, Pin, 2019; Stroud, 2010; Sunstein, 2001b, 2001a). Although the impact of these communication phenomena should not be exaggerated (Bruns, 2019; Dubois, Blank, 2018), homophily shapes, at least in part, the online environment (Bakshy, Messing, Adamic, 2015; Barberá, Jost, Nagler, Tucker, Bonneau, 2015; Colleoni, Rozza, Arvidsson, 2014; Conover et al., 2011), also with reference to vaccine-related communication (Schmidt et al., 2018). Since people also tend to gather around information sources consistent with their own viewpoint, and social media provide them the opportunity to share links, users' preferences regarding information sources emerge online (Bakshy et al., 2015; Faris et al., 2017; Giglietto et al., 2019b; Schmidt et al., 2017). The second research questions therefore asked:

RQ2) Was the structure of the Italian vaccine-related information environment on Twitter characterized by homophily? And if so, which clusters of information sources emerge?

Problematic health and political information cannot be easily disentangled. As recently observed (Lovari, Martino, Righetti, 2020), politicization can increase the circulation of problematic information on vaccines "both directly and by opening the door to pseudoscientific and conspiratorial content (...) published by problematic news sources" (p. 9). As a consequence, the strong politicization of vaccines during the debate on the law on mandatory vaccinations in Italy could have increased the volume of problematic information already spread online by anti-vaccine activists questioning official medicine (Kata, 2010, 2012), sowing doubts on vaccine safety, and spreading vaccine-related conspiracy theories (Blaskiewicz, 2013; Douglas et al.; Mancosu, Vassallo, Vezzoni, 2017). To deepen our understanding of online problematic information, the link between problematic political and health information should be further explored. It was thus asked:

RQ3) Was the volume of problematic information sources shared on Twitter related to the politicization of the topic?

Social media can be a means for propagating problematic information but also a tool for correcting "fake news" and disseminating high-quality health information (Bode, Vraga, 2018; Gesser-Edelsburg, Diamant, Hijazi, Mesch, 2018.; Guidry et al., 2019; Harrison et al., 2016; Larson, 2018; Sastry, Lovari, 2017; Vraga, Bode, 2017; Zhang, Gotsis, Jordan-Marsh, 2013). Recently, social media and websites have started to be used to support vaccine uptake, fight problematic health information, and spread scientific information. Social media platforms such as Facebook, Pinterest and Twitter, have taken steps to limit the diffusion of problematic information on vaccines (Facebook, 2019; Pinterest, 2019; Twitter, 2019), and online communication campaigns and websites were launched in Italy to promote vaccinations and scientific information (Lovari et al., 2020). Examples of these initiatives are 'Dottore, ma è vero che…?' ("Doctor is it true that…?") (FNOMCeO, 2018), "ISS Salute" ("ISS Health") (ISS, 2018a), and "Medical Facts" (Burioni, 2018). Despite the relevance of such initiatives, there is a lack of research designed to assess their role in the online environment. To start filling this gap, it was therefore asked:

RQ4) Were there changes over time in vaccine-related types and quality of information sources on Twitter in Italy?

3. Data and Methods

The tweets containing one or more of the words "vaccino", "vaccini", "vaccinazione", "vaccinazioni", "vaccinare"[4] published between 2016-02-01 and 2019-01-31 (three years) were collected[5]. The three-year time span includes 18 months before and after July 31, 2017, when the Italian law on mandatory vaccinations came into force. Around this date, the Twitter conversations on

[4] The keywords employed in this work ("vaccine", "vaccines", "vaccination", "vaccinations", "to vaccinate") are general terms and it is reasonable to assume they are included in most of the tweets on the topic. Thus, they are characterized by inclusivity, but also pre-empted the collection of too specific and biased streams of tweets (e.g.: Samantray, Pin, 2019). For instance, including a term such as "no-vax", which is used by people critical of the anti-vaccination movement, would imply gathering, mostly, messages ostile to the anti-vax movement.

[5] A Python script was used to gather the tweets from the Twitter historical search interface. Only public tweets were gathered, in accordance with all ethical standards.

vaccines skyrocketed (Figure 1), and many initiatives were launched to counter related problematic information (Lovari et al., 2020).

Tweets unrelated to the topic (for instance those on animal vaccines or about the band "The Vaccines") were removed, based on a list of keywords. The dataset used in the subsequent analysis comprised 484,618 original tweets. All the links (URLs) included in the tweets were extracted. Since Twitter shortens original URLs, they were converted back to their original form (Rudis, 2016). It was possible to identify 190,589 URLs from 9,658 domains (Table 1).

TABLE 1. Descriptive statistics of the Italian dataset of tweets on vaccines.

Period of Time	**2016-02-01/2019-01-31**
Tweets	484,618
Retweets	948,329
Likes	1,930,590
Replies	295,468
Unique Users	89,656
Unique URLs	190,589
Unique Domains	9,658

To focus on the most relevant information sources, the subsequent analyses were conducted on the web domains shared at an above average rate (M = 19, n = 1022 domains), corresponding to 82.14% of all the tweets that shared an URL (*Table 2*).

TABLE 2. Tweets taken into consideration in the analysis (categorized) and excluded from it (uncategorized).

Metric	**Categorized**	**Uncategorized**
Tweets	152,224 (82.14%)	33,103 (17.86%)
Likes	274,134 (86.28%)	43,593 (13.72%)
Retweets	211,648 (86.68%)	32,522 (13.32%)
Replies	48,102 (91.13%)	4,683 (8.87%)

To answer the first question (RQ1, "What was the volume of vaccine-related conversations on Twitter in Italy, and what were the main events that triggered them before, during and after the discussion on the law on mandatory vaccinations?"), the daily time series of tweets was analyzed to identify the events that might have determined the observed peaks of attention to the topic. A structural break statistical analysis (Box-Steffensmeier et al., 2014; Zeileis et

al., 2001) was run to identify possible periods marked by a statistically significant different volume of tweets[6]. The Kruskal-Wallis test followed by Dunn's post-hoc test[7] were used to assess statistically significant differences in the number of tweets and their engagement before, during and after the discussion on the Lorenzin decree on mandatory vaccinations.

To answer the second research question (RQ2: "Was the structure of the Italian vaccine-related information environment on Twitter characterized by homophily? And if so, which clusters of information sources emerge?") a network was created whose nodes were web domains (n = 1,022 shared in n = 152,224 tweets, which are all the domains shared a number of times above the average, see Table 2), and whose edges were relations between domains. All the web domains included in the analysis were manually classified by the author, by inspecting them and assessing their content against a taxonomy of information sources based on a previous study (Love, Himelboim, Holton, Stewart, 2013), which was further developed. The taxonomy included, among others, the following categories of information sources: news media, conspiracy theories, alternative therapies, health specific sources, anti-vaccines, pro-vaccines, health organizations, and scientific communication. Moreover, the categories were supplemented by a list of 376 web domains compiled by aggregating blacklists retrieved from established Italian debunking organizations which were already used for the same purpose (e.g.: Fletcher et al., 2018; Giglietto et al., 2020; Lovari et al., 2020). Since every clustering method has its own limitations, six different clustering algorithms[8] were used to identify the clusters of information sources. Four clustering methods (namely Louvain, Fast Greedy, Leading Eigen and Walktrap) identified two or more clusters in the data, while two clustering methods proved unable to segment the data into groups of sources. The results of the first four algorithms were kept, based on the consideration that most clustering methods agreed that two or more groups of sources could be found in the data, and it was theoretically unlikely, in the light of previous research on the topic, that no cluster of information sources (even more or less overlapping) could be found. Then, a correspondence analysis was run on the matrix N

[6] "A structural break occurs when an entire series is no longer characterized by the same underlying process, and instead, there are two (or more) distinct subsamples of the observations, each of which is characterized by a unique underlying process. Such breaks may either be the result of an observed event or of an unobserved combination of factors" (Box-Steffensmeier et al., 2014: 65).

[7] The Kruskal-Wallis test is a non-parametric method for testing whether samples originate from the same distribution. A post-hoc test (Dunn's test) follows a statistically significant test to find which groups are statistically different, in terms of stochastic dominance, from the others.

[8] The algorithms are included in the R package "igraph" (Csardi, Nepusz, 2006).

(clusters) x M (information source categories), eventually aggregating the group of categories distributed on the cartesian plane in the final clusters of information sources[9].

The third research question (RQ3: *"Was the volume of problematic information sources shared on Twitter related to the politicization of the topic?"*), was answered by using a breakpoints statistical analysis (Zeileis et al., 2001) to identify possible structural breaks in the time series of tweets sharing problematic information sources and compare them with the events that could have led the conversation. The rationale was that an association with politicization could result in a structural break in correspondence with the political debate on the mandatory vaccination law. Then, a time series regression model was fitted by using the following variables: a) the daily time series of the cluster of problematic information sources which emerged from the previous step[10]; b) the daily time series of Italian news stories on vaccines retrieved from MediaCloud[11] by using the same keywords used for gathering the tweets. This variable was used as a proxy for the media attention to the topic[12], and as a control variable, because its (possible) relation with the volume of problematic information could confound the relation of the latter with politicization; c) a dummy variable representing the structural break identified (as will be detailed in the next section) in the whole series of tweets. This structural break was clearly associated with the politicization of vaccinations during the debate on the mandatory vaccinations law and was thus used as a proxy for the politicization of the topic. A Vector Auto-Regressive model (VAR) was fitted to find possible statistically significant relations between these variables and, more specifically,

[9] Correspondence analysis produces graphical representations on which the geometrical proximities among row-points and column-points of a contingency table translate statistical associations among rows (in the current case, the categories of information domains) and columns (the clusters of sources as identified by the four different clustering algorithms) (e.g.: Husson, Pagès, 2017).

[10] The cluster of problematic information sources will be described in the next sections. The following categories were included: Offline Blacklisted, Other Blacklisted, News Blog, Alternative Therapy, News Media Blacklisted, Health Specific Blacklisted, Vaccine Specific (Anti), Conspiracy, News Blog Blacklisted, Alternative Therapy Blacklisted.

[11] MediaCloud (https://mediacloud.org) is an open-source platform for media analysis developed and maintained by the MIT Center for Civic Media and the Berkman Klein Center for Internet & Society at Harvard University.

[12] Roughly the same results were also found by using, instead of the MediaCloud data, the time series of tweets sharing domains categorized as news media.

between the spread of problematic information and the politicization of the topic[13].

The fourth and last research question (RQ4: "Were there changes over time in vaccine-related types and quality of information sources on Twitter in Italy?") was answered by calculating the average number of tweets sharing information sources included in the identified clusters and comparing their change over time through "index numbers", a standard method to measure the change in a variable or group of variables over time[14]. The R statistical software was used for all the analyses (R Core Team, 2019).

4. Results

Twitter conversations on vaccines reached their peak in the middle of 2017 (Figure 1), when the "Lorenzin decree" on mandatory vaccines started to be debated and eventually became law (Casula, Toth, 2018). The breakpoints statistical analysis (Zeileis et al., 2001) showed that this political event caused a significant shock to the usual flow of vaccine-related conversations on Twitter (Figure 1 and Table 3).

Another spike, while much less pronounced than the previous one, was triggered by the 2018 electoral campaign, when the main political parties competing in the 2018 Italian General Election made reference to the law on

[13] Time series require specific statistical techniques to fit regressions. VAR (vector autoregressive models) are used to model the variables as a function of their own previous ("lagged") values and the previous values of the other variables. The variables can be either endogenous or exogenous. Exogenous variables can have an impact on the endogenous variables, while the opposite is not true. The dummy variable accounting for politicization was considered an exogenous variable, since it can impact both the news coverage of the topic and the spread of problematic information on Twitter, while it was assumed that the political debate that led to the promulgation of the law on mandatory vaccinations was independent from the Twitter discussions on the topic. VAR requires the researcher to set the number of lags to be used. This number was identified through the lag-length selection criteria method implemented in the R "vars" library (resulting in 2 lags). Variables were log-transformed to take care of spikes. Appropriate analysis of residuals was performed to check the assumptions were successfully met. Also, Granger causality test, which is a test to assess if a variable is helpful in forecasting another variable, was implemented to assess the relation between the two endogenous variables included in the model.

[14] Index numbers are a standard approach used to measure changes and simplify comparisons. The method requires the researcher to select a base time period and set the value of that period to a value, usually 100). The values at the other periods represent the percentage change from the base period.

child vaccinations, either by defending it or promising its repeal (Casula, Toth, 2018; Lovari et al., 2020). Since the Lorenzin law imposes vaccinations as a prerequisite for school admission, it is also not surprising to find peaks of conversations near the beginning of the school years.

FIGURE 1. Annotated time series of the Italian tweets on vaccines. The red box indicates the boundaries of the structural break.

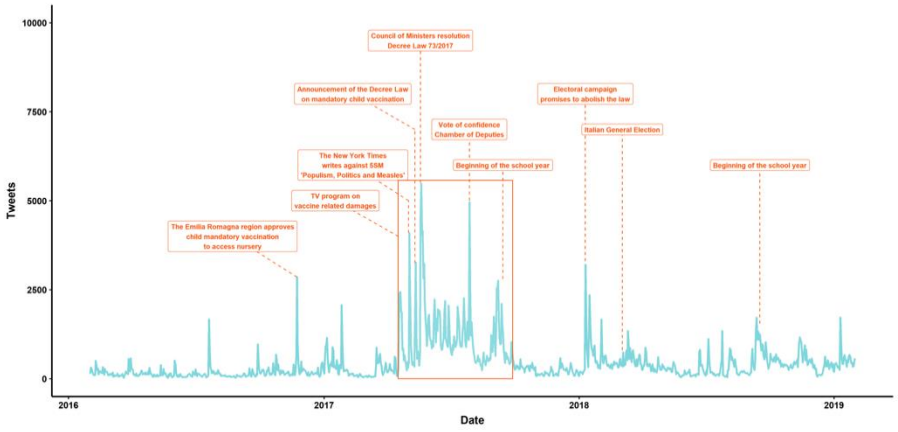


TABLE 3. Structural break analysis. A structural break (segment 2) emerged in the period of discussion and approval of the law on mandatory vaccination.

Coefficients	**Estimate**	**Std. Error**	**t value**	**Pr(>|t|)**
Segment 1 (2016-02-01 / 2017-04-17)	86.624	6.796	12.75	< 0.001 ***
Segment 2 (2017-04-18 / 2017-09-28)	420.555	11.156	37.70	< 0.001 ***
Segment 3 (2017-09-29 / 2019-01-31)	91.765	6.454	14.42	< 0.001 ***
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				
Residual standard error: 142.9 on 1093 degrees of freedom Multiple R-squared: 0.6203, Adjusted R-squared: 0.6193 F-statistic: 595.2 on 3 and 1093 DF, p-value: < 0.001				

Although the debate on mandatory vaccination fostered conversations on vaccine-related topics on Twitter in an unusual way, *the discussions on the matter*

showed no sign of letting up after that period. On the contrary, the daily volume of tweets (Table 4) as well as their engagement (Table 5) continued to be high, and even statistically significantly higher ($p < 0.001$) than those of the first period.

TABLE 4. Volume of tweets before, during and after the discussion on the Lorenzin decree. Dunn's post-hoc test with Bonferroni correction following a significant Kruskall-Wallis test (Kruskal-Wallis chi-squared = 328.1232, df = 2, p-value = 0).

	Segment 1 (2016-02-01 / 2017-04-17)	**Segment 2 (2017-04-18 / 2017-09-28)**
Segment 2 (2017-04-18 / 2017-09-28)	-17.66337 0.0000*	
Segment 3 (2017-09-29 / 2019-01-31)	-2.943320 0.0049*	15.76200 0.0000*

TABLE 5. Tweets engagement before, during and after the discussion on the Lorenzin decree. Dunn's post-hoc test with Bonferroni correction following a significant Kruskall-Wallis test (Kruskal-Wallis chi-squared = 397.9715, df = 2, p-value = 0).

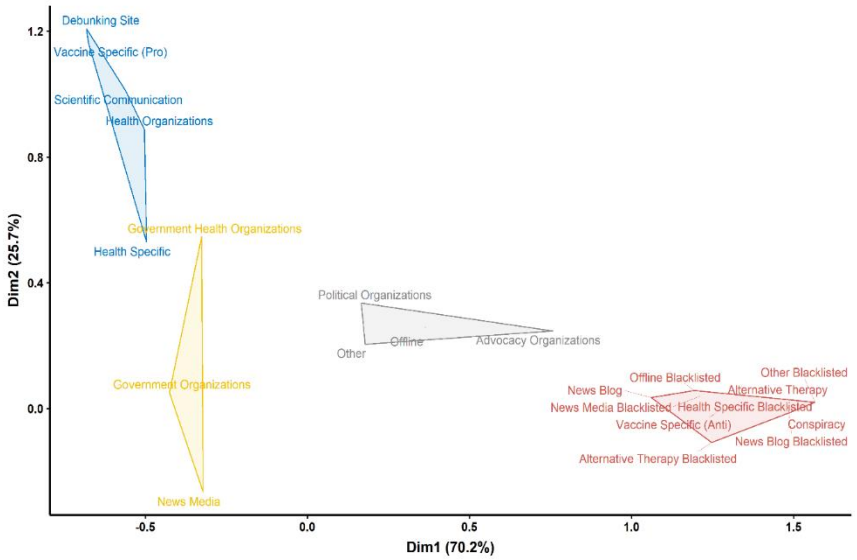
	Segment 1 (2016-02-01 / 2017-04-17)	**Segment 2 (2017-04-18 / 2017-09-28)**
Segment 2 (2017-04-18 / 2017-09-28)	-18.31781 0.0000*	
Segment 3 (2017-09-29 / 2019-01-31)	-14.22709 0.0000*	8.220182 0.0000*

Regarding the second research question (RQ2), a clustering analysis followed by a correspondence analysis found four main clusters of information sources (Figure 2). Consistent with the homophily principle, anti-vaccine information sources were clustered together with conspiracy, alternative therapies, blacklisted websites (websites known for spreading problematic information online), and news blogs (websites that publish articles for profit, to put forward a political agenda or as a hobby, without being professional journalistic sources), while pro-vaccine sources were grouped with the scientific and debunking ones. A third cluster grouped political sources, and the fourth included mainstream media along with institutional information sources.

Considering the results of the correspondence analysis, it appears clear that the main dimension (accounting for 70.2% of the total variance) contrasts the alternative and problematic information sources against the mainstream and scientific ones, while the political cluster seems to lie in between these two polarities. This result corroborates the idea that the vaccine-related information environment mirrors the contrasts between the anti-vax and pro-vax

perspective, or, in other words, is characterized by a consistent degree of homophily and polarization.

FIGURE 2. Clusters of information sources shared on Twitter.



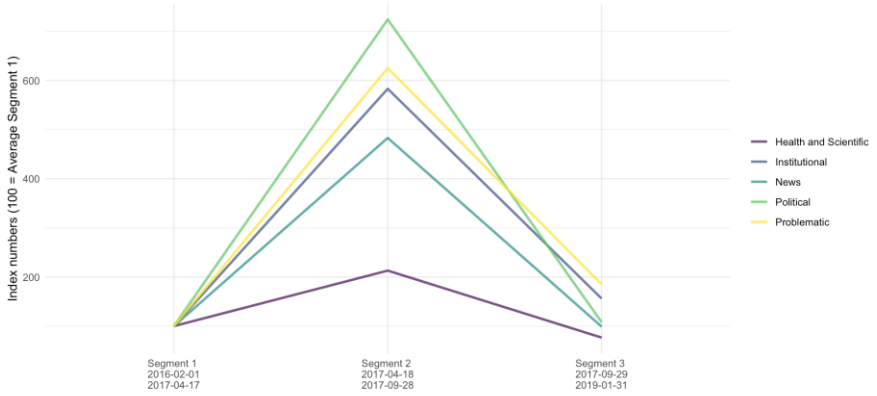
The quantity of tweets sharing problematic news sources varied over time, and the analyses showed that politicization was associated with an increased number of both total tweets and those sharing problematic information sources (RQ3). A significant structural break in the series of tweets sharing problematic sources was found, indeed, in almost perfect correspondence with the structural break in the whole series of tweets, that is, during the political debate on the mandatory vaccinations law[15]. A smaller spike in the series of tweets sharing problematic information was found after August 18, 2018, some weeks before the school year began, during the government led by the League and Five Star Movement, two parties that promised the repeal of the law on mandatory vaccinations, thus raising expectations about change in the vaccination norms (Lovari et al., 2020).

[15] The structural break in the whole series was found between 2017-04-17 and 2017-09-28, while the one in the tweets sharing problematic sources was found between 2017-04-16 and 2017-09-27.

The evidence suggested, therefore, that politicization had a significant impact on both the Twitter information flow and that of problematic information. A VAR regression further confirmed this observation. The analysis found that politicization, represented by the structural break matching the political debate of mid-2017, kept being significantly ($p < 0.001$) associated with the increase in the spread of problematic information and the volume of media coverage even after controlling for the past two lags of news media coverage and problematic information[16,17].

Finally, considering the changes in information sources shared before, during and after the major peak in vaccine-related discussion in the middle of 2017 (RQ4), results showed that, when the discussion on Twitter reached its peak, there was a lack of scientific and quality health information (*Figure* 3).

FIGURE 3. Changes in average volume of tweets.



While, on average, the number of tweets sharing problematic information was about 6 times higher than the previous period, and similarly the volume of the other categories of information sources increased from about five to about seven times, the average number of tweets sharing scientific sources increased by only about twice (Figure 3). Moreover, while on average all the categories increased their presence on Twitter from before and after the debate on

[16] Let M be the series of tweets sharing problematic information (endogenous variable), N the series of tweets sharing news media (endogenous variable), and P the series indicating politicization (exogenous variable), the VAR model resulted as follows:
$\widehat{M}_t = 0.47187 + 0.53139M_{t-1} + 0.22529M_{t-2} + 0.44717N_{t-1} - 0.17233N_{t-2} + 0.29202P_t$
$\widehat{N}_t = 0.146301 - 0.009643M_{t-1} - 0.003379\,M_{t-2} + 0.550706N_{t-1} + 0.051055N_{t-2} + 0.1315P_t$

[17] Besides being associated with politicization, problematic information resulted associated with news media coverage, as showed by a Granger causality test ($p < 0.001$).

mandatory vaccination of mid-2017, the health and scientific cluster was the only one that decreased, on average, its online presence.

5. Discussion and conclusions

It has been observed that politicization of a crucial health issue such as vaccinations can be a vehicle for the spread of problematic information (Lovari, Maritino, Righetti, 2020). This study found further evidence of the role of politicization in increasing the volume of problematic information on social media. Indeed, the study has shown that the heated political debate on the mandatory vaccination law was associated with an increase in the number of tweets sharing problematic information sources such as conspiracy, anti-vax, hyperpartisan, and blacklisted sources (Blaskiewicz, 2013; Briones et al., 2012; Douglas et al., 2019). It has been shown, moreover, that during the political debate about the law, when attention to the topics was at its highest, the volume of tweets sharing scientific and health information sources increased much less (just twice that of the previous period) compared with the volume of tweets sharing problematic information, which increased, on average, by over 6 times.

Sources of problematic information were shared on Twitter both before and after the promulgation of the law on mandatory child vaccination. However, this study showed that they grew in volume after mid-2017, compared to the first period taken into consideration, demonstrating that vaccine-related problematic information had not ceased to be a problem and suggesting that the politicization of the topic (Gollust et al., 2016; Lovari et al., 2020) might have had a long-lasting impact on the online attention devoted to it, a matter that deserves further examination. At the same time, the number of tweets sharing scientific information sources decreased over time.

The study confirmed the role of homophily (Lazarsfeld, Merton, 1954; McPherson, Smith-Lovin, Cook, 2001) in structuring the networks of social media users and information sources involved in the discussion around the controversial and polarizing issue of vaccines (Schmidt et al., 2018). The sharp distinction between the pro-vaccine and anti-vaccine cluster of information sources indicates that Twitter users with contrasting views relied on different sources of information. This could be interpreted as a sign that social media users are trapped in echo-chambers (Gunaratne et al., 2019; Schmidt et al., 2018), but it may also point to a strategic use of information sources shared on Twitter to support and spread a view (Kata, 2010, 2012; Moran, Lucas, Everhart, Morgan, Prickett, 2016), since the sharing of URLs can be associated with a persuasive writing style (Addawood et al., 2019: 19).

This research also stressed the methodological relevance of homophily for the digital analysis of subcultures. The performed analysis showed that the anti-vaccine sources were clustered together with alternative therapy and conspiracy theory websites. The anti-vaccine movement, indeed, often goes hand in hand with the endorsement of naturalistic theses, interest in alternative therapies, and hostility towards official medicine, which is the subject of conspiracy theories (Blaskiewicz, 2013; Briones et al., 2012; Douglas et al., 2019; Mancosu et al., 2017), such as those that accuse governments and pharmaceutical companies of getting rich at the expense of the people's health. Because of its ability to identify different facets of socio-cultural phenomena, the method can be further developed and applied to the analysis of a variety of cases.

This study has also some limitations that must be noted. First, the keyword-based strategy used to collect the data, although kept as neutral as possible, may have introduced some biases. Although completeness and unbiasedness are hard to achieve in studies like this, given the many and unpredictable ways people talk about a topic online, future research could try to use a wider set of keywords to achieve a higher level of completeness. Future research should also shine a light on other social media. Indeed, we have recently witnessed the migration of many extreme, anti-establishment groups, from mainstream social media such as Facebook, Instagram, Twitter and YouTube, to alternative social media (Rogers, 2020). Even if the mainstream social media continue to be relevant because they guarantee the anti-vaccination movement an audience to persuade and engage, it is also important to investigate the evolution of the anti-vaccination phenomenon on alternative channels. Another limitation concerns the limited time period considered. Three years might be too short a period of time to fully understand trends, and other analyses might consider a longer time frame. However, this choice made it possible to analyze an equal amount of time before and after the promulgation of the law on mandatory vaccinations. Finally, future research should try to find more precise measures of politicization – in this paper measured by a proxy variable – and try different statistical strategies to assess its impact on the spread of problematic information.

Despite these limitations, the study demonstrates that the heated debate sparked by the Italian law on mandatory child vaccination, and the subsequent politicization of the topic, created a breeding ground for problematic information on Twitter, that problematic information on vaccines, alongside polarization, is still a problem, and that scientific information was not able to counteract problematic health information. The relation between politicization and problematic health information deserves further analyses, as do the role and impact of scientific communication on social media and its interactions with problematic information and the politicization of health. Such analyses might

consider deploying more sophisticated measures and methods able to account for the complexity of online and offline information and the political environment.

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