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The Internet and the Anti-Vaccine Movement: Tracking the 2017 EU Measles Outbreak

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Abstract: In the Internet Era of information overload, how does the individual filter and process available knowledge? In addressing this question, this paper examines the behavioral changes in the online interest in terms related to Measles and the Anti-Vaccine Movement from 2004 to 2017, in order to identify any relationships between the decrease in immunization percentages, the Anti-Vaccine Movement, and the increased reported Measles cases. The results show that statistically significant positive correlations exist between monthly Measles cases and Google queries in the respective translated terms in most EU28 countries from January 2011 to August 2017. Furthermore, a strong negative correlation ($p < 0.01$) exists between the online interest in the term 'Anti Vaccine' and the Worldwide immunization percentages from 2004 to 2016. The latter could be supportive of previous work suggesting that conspiracist ideation is related to the rejection of scientific propositions. As Measles require the highest immunization percentage out of the vaccine preventable diseases, the 2017 EU outbreak could be the first of several other diseases' outbreaks or epidemics in the near future should the immunization percentages continue to decrease. Big Data Analytics in general and the analysis of Google queries in specific have been shown to be valuable in addressing health related topics up to this point. Therefore, analyzing the variations and patterns of available online information could assist health officials with the assessment of reported cases, as well as taking the required preventive actions.

Keywords: anti-vaccine; anti-vaccine movement; Google Trends; Internet; measles; MMR; online behavior; vaccination

1. Introduction

It was in 1998 when Wakefield et al. [1] published a paper in the Scientific Journal 'The Lancet', suggesting that they identified "*a chronic enterocolitis in children that may be related to neuropsychiatric dysfunction. In most cases, onset of symptoms was after measles, mumps, and rubella immunisation*". This study was conducted on a sample of 12 children, with the overall interpretation of the results being—in simple words—that autism is associated with the Measles-Mumps-Rubella (MMR) vaccine [2]. The claims of this study have since been proven to be false, with over 20 epidemiologic studies showing that no causality or relationship exists between vaccination and autism [3]. Said studies were methodologically solid, i.e., conducted in several countries and by different researchers, while employing epidemiologic and statistical methods for large population sizes. Furthermore, a meta-analysis of more than 40 studies showed that no links between vaccination and autism exist [4].

After the panel hearing where Andrew Wakefield lost his medical license in January 2010 [5], 'The Lancet' retracted the paper, stating that: "*Following the judgment of the UK General Medical Council's Fitness to Practise Panel on Jan 28, 2010, it has become clear that several elements of the 1998 paper by Wakefield et al. are incorrect, contrary to the findings of an earlier investigation. In particular, the claims in the*

original paper that children were "consecutively referred" and that investigations were "approved" by the local ethics committee have been proven to be false. Therefore we fully retract this paper from the published record" [6].

It was at that point when the Anti-Vaccine Movement started to become publicly known, while the retraction of the paper and Wakefield losing his license was the beginning of one of the most well-known conspiracy theories, i.e., that the MMR vaccine causes autism and thus vaccination should be avoided. Said Anti-Vaccine skepticism does not only refer to the MMR, but has been widened to include vaccines in general. This reaction comes not as a surprise, as it has been shown in the past that the rejection of scientific propositions and conspiracist ideation are related [7].

Was the rise of the Anti-Vaccine Movement a result of the public's attraction to conspiracy theories? Was it a result of the past years' increased Internet penetration? Was it a combination of the two? In any case, what can now be observed is a decrease of the immunization coverages in most of the EU countries, resulting in the recent EU Measles outbreak. Specifically, despite that the reported Measles cases decreased in 2009, they experienced an increase by "*a factor of four between 2010 and 2011*" [8]. Out of the vaccine preventable diseases, Measles require the highest immunization percentage coverage [9]. If the EU28 immunization percentages continue to drop, how long will it be before we are talking about an epidemic?

Almost 20 years have passed since Wakefield's [1] study was published, but we are only now able to clearly see the effects of the Anti-Vaccine Movement on public health. Though over the past decades we as a society managed through vaccination to significantly decrease death rates caused by the respective diseases, the spreading of such bogus arguments has resulted in the reappearance of several vaccine preventable diseases, as is the case of Measles. Before the age of the Internet, news channels, newspapers, and other forms of official information sources would not so easily and with such high speed reproduce studies and claims that were not proven to be correct. This is unfortunately the case today in blogs, forums, and social media, constituting a perfect example of how a great life-changing discovery like the World Wide Web could be used to negatively affect public health.

In order to investigate the behavior towards Measles and the Anti-Vaccine Movement, we use data from Google Trends [10], a popular open tool for examining online behavior in Big Data Analytics [11,12]. Subject to careful selection of the examined terms for robust results [13], online queries have been suggested to be beneficial in analyzing behavioral changes [14], while the value and validity of Google Trends' data have been highlighted by previous work on the subject [15,16]. Over the past decade, data from Google Trends have been used to examine the behavior towards several health related topics [17]. As Google Trends' data provide information on the revealed and not the stated users' preferences, they have been shown to assist with the assessment of human behavior in health issues, and that empirical relationships between online search traffic data and official health data exist. For example, Google queries on the respective selected terms have been shown to correlate with suicide rates [18,19], prescription drugs issuing [20,21] and revenues [22], and influenza [23,24]. In addition, online queries have also been shown to be valuable in predicting, detecting, and assessing epidemics and outbreaks [25–27].

Google Trends' data have been effectively employed up to this point in the fields of health and medicine in assessing behavioral changes and in examining relationships that exist between online behavior and human behavior. Towards contributing to the discussion of how online search traffic data can be used in order to analyze and predict human behavior, we first examine the online behavioral variations towards Measles and the Anti-Vaccine Movement from January 2004 to August 2017, Worldwide and in the EU28. Furthermore, we identify the relationships between Google queries and immunization percentages, and investigate the Internet's role in the 2017 EU Measles outbreak—caused by decreased immunization—in relation to the overall Anti-Vaccine skepticism.

The rest of the paper is structured as follows: Section 2 covers the methodology and the procedure of the data collection, the results are presented in Section 3 and discussed in Section 4, while Section 5 consists of the overall concluding remarks.

2. Data and Methods

Data from Google Trends are downloaded online in '.csv' format and are normalized over the selected period. Google reports the adjustment procedure as follows: "*Search results are proportionate to the time and location of a query: Each data point is divided by the total searches of the geography and time range it represents, to compare relative popularity. Otherwise places with the most search volume would always be ranked highest. The resulting numbers are then scaled on a range of 0 to 100 based on a topic's proportion to all searches on all topics. Different regions that show the same number of searches for a term will not always have the same total search volumes*" [28]. Depending on the retrieval time, data may slightly vary.

In this study, the examined period is from 1 January 2004 to 31 August 2017. The retrieved normalized data are monthly, with the number of observations being N = 164 (months), i.e., 13 years × 12 months + 8 months for each examined dataset. The datasets are 59 in total, i.e., 28 countries (English term) + 26 countries (translated terms excluding Ireland and the UK) + 5 Worldwide. The examined keywords are the English term 'Measles' and the respective translated terms, retrieved separately (independent searches, not comparisons) for each of the examined terms and for each of the examined EU countries. For the Worldwide assessment, the keywords 'Measles', 'Mumps', 'Rubella', 'MMR', and 'Anti Vaccine' were used.

The selected countries are the EU28 (translation of the term 'Measles' in the respective language in the parenthesis, obtained via Google Translate [29]): Austria (masern), Belgium (rougeole/mazelen), Bulgaria (дребна шарка), Croatia (ospice), Cyprus (ιλαρά), Czech Republic (spalničky), Denmark (mæslinger), Estonia (leetrid), Finland (rougeole), France (rougeole), Germany (Masern), Greece (ιλαρά), Hungary (kanyaró), Ireland (measles), Italy (morbillo), Latvia (masalas), Lithuania (tymai), Luxembourg (rougeole/mëllech), Malta (ħosba), Netherlands (mazelen), Poland (odra), Portugal (sarampo), Romania (pojar), Slovakia (osýpky), Slovenia (ošpice), Spain (sarampión), Sweden (mässling), and the UK (measles).

Google Trends is not case-sensitive, but it does take into account accents. Thus, for each country that is not English speaking and the respective term for Measles contains accents or any letter variations, relevant differentiation of terms were compared, and the term with the most search volumes was selected. Only Spain, Greece, and Cyprus exhibited highest interest in the respective translated term without accents, i.e., sarampion, ιλαρα, and ιλαρα, respectively; thus, the latter were used for the analysis. For the rest of the countries, the terms are used exactly as written above. Furthermore, the English term's online interest in each of the EU28 countries was examined, as the term 'Measles' exhibited high search volumes in many countries, and could, therefore, not be excluded from the analysis.

In order to analyze the interest in the Anti-Vaccine Movement, the following terms were compared: 'anti vaxx', 'anti-vaxx', 'anti vacc', 'anti-vacc', 'anti vax', 'anti-vax', 'anti vaccine', and 'anti-vaccine'. For the analysis to be robust, the term should be carefully selected; thus, as the term with significantly higher search volumes was 'Anti Vaccine', it is the one used in order to assess the Worldwide interest in the Anti-Vaccine Movement. For this study, the analysis consists of the following steps:

(a) Assessment of the Worldwide changes in the online interest in the the terms 'MMR' and the repsective diseases, i.e., 'Measles', 'Mumps', and 'Rubella',
(b) Analysis of the online interest in the English and the respective translated terms for 'Measles' for the selected period in all EU28 countries,
(c) Concise presentation and analysis of the 1st and 2nd MMR doses immunization percentages in Europe and the EU28,
(d) Examining of the relationships between online activity, vaccine population coverage (obtained through the WHO website [30]), and reported cases of Measles in each of the EU28 countries, by calculating the Pearson Correlation coefficients.

Data on country immunization percentages and reported Measles cases are obtained by the World Health Organization (WHO) [30], and defined by WHO as "*laboratory confirmed, epidemiologically linked, and clinical cases as reported to the World Health Organization*" [31].

3. Results

This section consists of the analysis of the Worldwide and the EU28 countries' online interest in terms related to Measles and the Anti-Vaccine Movement, followed by the examining of the relationships between Google Trends' data, vaccine population coverage, and reported cases.

3.1. Worldwide Online Interest

Figure 1 depicts the online interest in the terms 'Measles', 'Mumps', 'Rubella', and 'MMR' from 1 January 2004 to 31 August 2017. Note that for the term 'MMR', the results may be increased at points due to the same abbreviation shared with online gamers, though this does not affect the results, as the peaks and overall interest variations of the 'MMR' term are similar to the aforementioned diseases.

The related queries from 2004 to 2017 for the term 'Measles' include 'measles symptoms' (100), 'measles vaccine' (75), 'measles rash' (75), 'measles outbreak' (45), 'symptoms of measles' (30), 'mmr' (25), 'measles vaccination' (20), 'vaccination' (20), and 'measles treatment' (20). For the term 'Mumps', the related queries for the same period include 'symptoms mumps' (100), 'measles mumps' (65), 'mumps vaccine' (35), 'mumps adults' (25), 'mumps treatment' (20), 'mmr' (20), 'mumps disease' (15), and 'mumps outbreak' (15). For Rubella, the related queries include 'measles rubella' (100), 'rubella vaccine' (85), 'rubella virus' (70), 'rubella pregnancy' (50), 'what is rubella' (40), 'rubella rash' (35), 'rubella symptoms' (35), 'rubella test' (30), 'mmr' (25), 'measles rubella vaccine' (20), 'congenital rubella' (20), 'rubella syndrome' (20), and 'rubella in pregnancy' (20). For the MMR vaccine, the related queries from 2004 to 2017 include 'mmr vaccine' (100), 'autism' (20), 'what is mmr' (20), 'autism mmr' (20), 'mmr side effects' (15), 'mmr vaccination' (10), 'vaccination' (10), 'check mmr' (10), 'vaccines' (10), 'mmr vaccines' (10), 'mmr vaccine autism' (10), and 'mmr shot' (10).

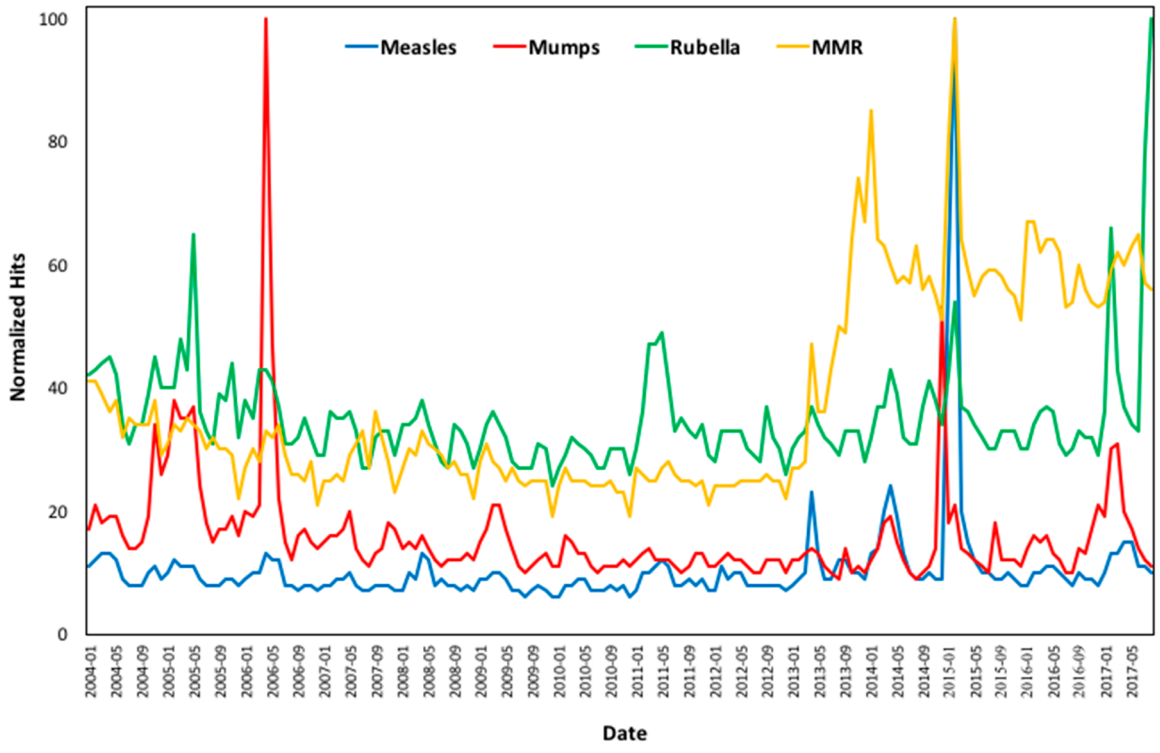

Figure 1. Worldwide Interest in 'Measles', 'Mumps', 'Rubella', and 'MMR' from 2004 to 2017.

All four examined terms exhibit similar behavior during the examined period, i.e., from January 2004 to August 2017. The interest peaks at several points during this time, while increased interest is evident in January 2015. This can be attributed to the 2015 Measles outbreak in Disneyland with 32 confirmed cases, most of them regarding unvaccinated people [32,33].

Figures 2–5 depict the Worldwide interest by country over the examined period for the terms Measles, Mumps, Rubella, and MMR, respectively. Note that the gray color indicates no significant results in search volumes, i.e., the score is zero.

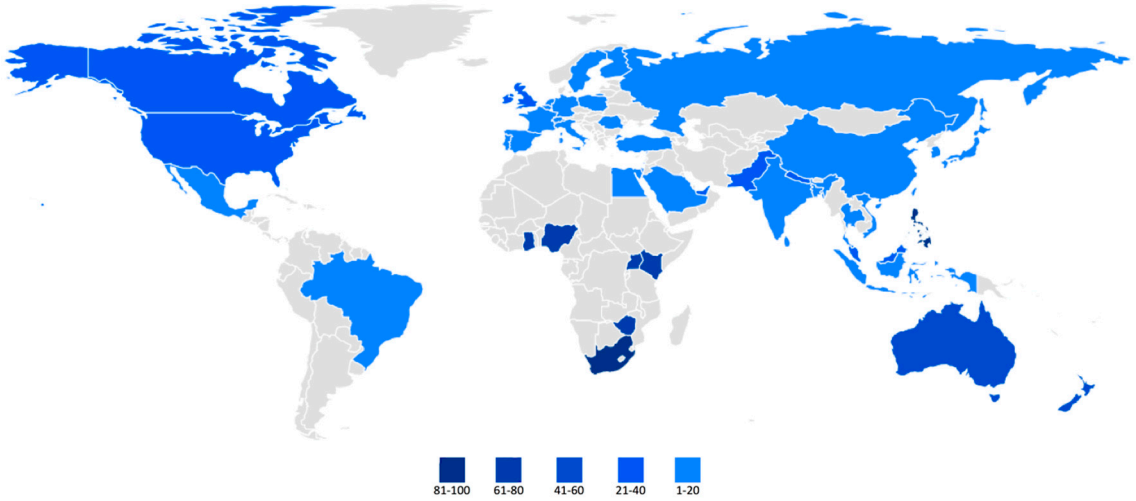

Figure 2. Worldwide Interest by Country in Measles from 2004 to 2017 (gray indicates zero scoring).

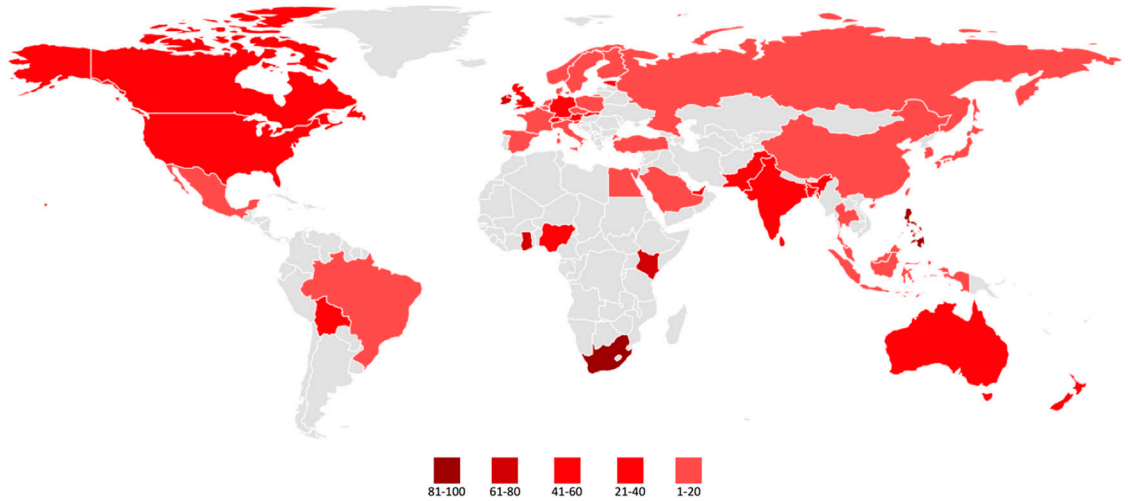

Figure 3. Worldwide Interest by Country in Mumps from 2004 to 2017 (gray indicates zero scoring).

In all terms, moderate interest is exhibited in Europe, Asia, and Northern America. However, the highest interest is observed in some countries in Africa, despite the fact that most countries have zero scoring, i.e., the search volumes are not high enough to be examined. The following African countries show constant interest in the three diseases: South Africa scores 89 in Measles, 100 in Mumps, 19 in Rubella, and 12 in MMR. Kenya exhibits high interest in Measles (67) and Mumps (72), and lower in Rubella (21); Ghana also exhibits higher interest in Measles (70) and Mumps (70), and lower in Rubella (22); Nigeria scores 67 in Measles, 53 in Mumps, and 11 in Rubella. Note that South Africa is the only country in the continent to have search volumes for the term 'MMR' high enough to be analyzed.

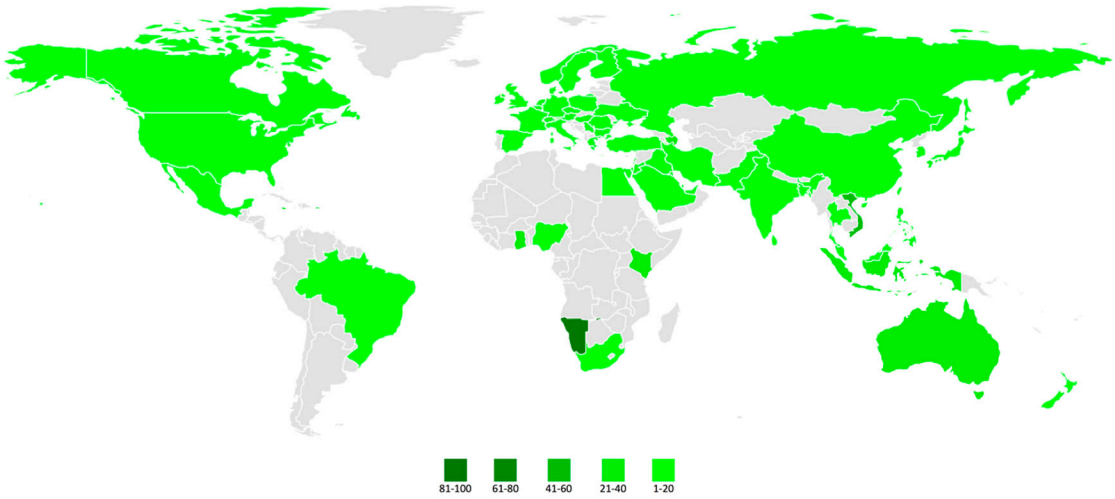

Figure 4. Worldwide Interest by Country in Rubella from 2004 to 2017 (gray indicates zero scoring).

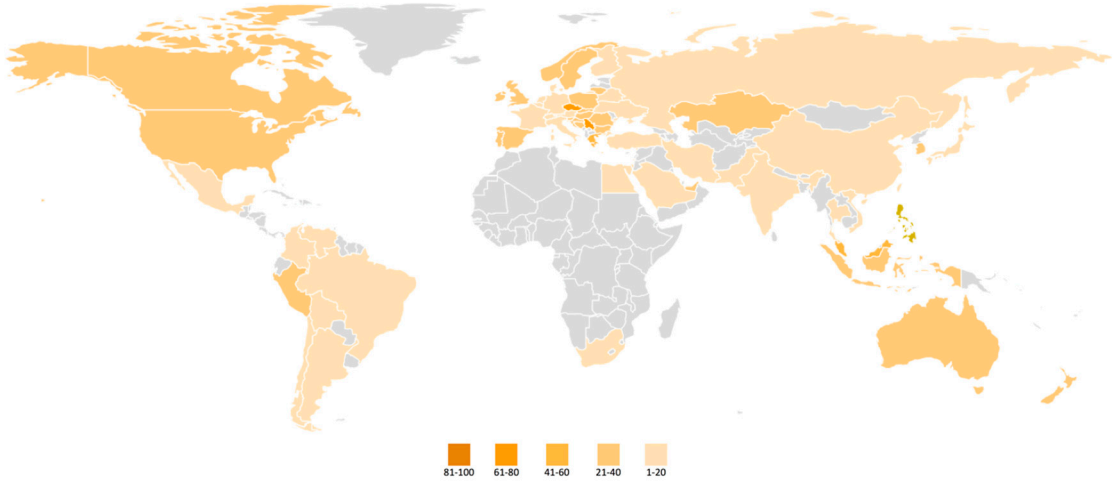

Figure 5. Worldwide Interest by Country in MMR from 2004 to 2017 (gray indicates zero scoring).

Figure 6 depicts the changes in the online interest in the term 'Anti Vaccine' from 1 January 2004 to 31 August 2017. The country with the highest search volumes is Canada (100), followed by Australia (96) and USA (93). The related queries include 'anti vaccine movement' (100), 'anti vaccination' (30), 'why anti vaccine' (20), 'measles' (15), 'anti vaccine doctors' (15), 'anti vaccine arguments' (15), 'anti vaccine celebrities' (10), 'anti vaccine websites' (5), 'andrew wakefield' (5), and 'measles outbreak' (5).

The online interest in the Anti-Vaccine Movement is rising, as all the more Internet users look for online information about anti-vaccination. What should be noted at this point is that the public searched for the terms 'anti vaccine arguments' and 'anti vaccine celebrities' in large volumes, which could be a worrying statement about how people choose to inform themselves in such crucial matters for public health.

A peak is observed in January 2010, which coincides with Wakefield losing his license [5], while the peak over the whole examined period, i.e., from 2004 to 2017, is observed in 2015, which could be attributed to the Measles outbreak in Disneyland [33]. This peak is during the same time that the online interest for the terms 'Measles', 'Mumps', 'Rubella', and 'MMR' also peaks (Figure 1). Overall, as depicted in Figure 6, the online interest for the term 'Anti Vaccine' has significantly increased over the past 13 years, with the average interest in 2017 being more than 10 times higher than what it was in 2004.

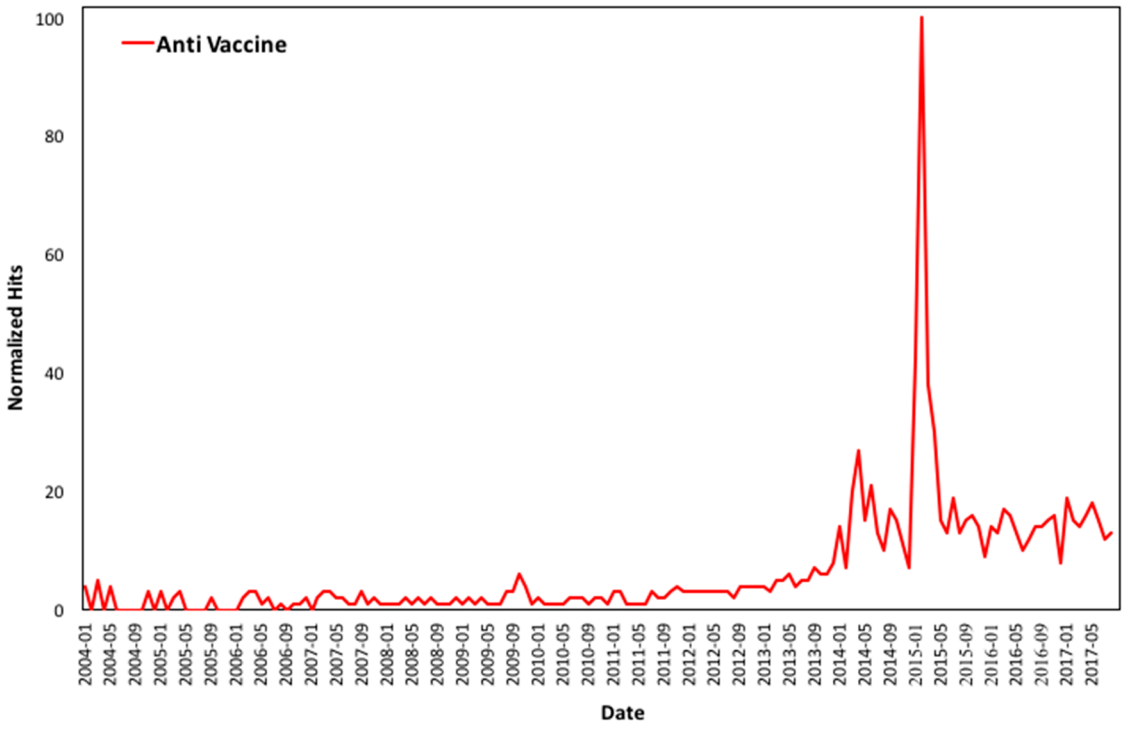

Figure 6. Worldwide Online Interest in the term 'Anti Vaccine' from January 2004 to August 2017.

In order to explore the links between the Anti-Vaccine Movement and the immunization percentages Worldwide, the Pearson Correlation coefficients are calculated. The yearly averages for the normalized Google queries for the term 'Anti Vaccine' (Worldwide) and the global population coverage of the 2nd dose of the vaccine for Measles from 1 January 2004 to 31 December 2016 exhibit a high negative correlation ($r = -0.7627$, $p < 0.01$).

For the years 2004–2015 and 2004–2014, Google queries and the 2nd dose population coverage are also highly (negatively) correlated ($r = -0.71$ with $p < 0.01$, and $r = -0.7076$ with $p < 0.05$, respectively). This indicates that the immunization coverage decreases as the online interest in the term 'Anti Vaccine' increases. Though statistically significant differences are not observed for the periods from 2004 to 2013 and from 2004 to 2012, the relationship is still negative. Correlations between the population coverage for the 1st dose of the Measles vaccine and the Worldwide online interest in the term 'Anti Vaccine' were not observed, which could be attributed to the time gap for the suggested age between the 1st and 2nd dose of the Measles vaccine.

3.2. EU28 Online Interest

Figure 7 depicts the monthly normalized (measured in a scale from 0 to 100) Google Trends' data in the English term 'Measles' (blue) and its respective translations (red) in all EU28 countries from January 2004 to August 2017 (independent searches, not comparisons).

Most countries exhibit increased interest in early 2015, thus supporting the argument that the Disneyland Measles outbreak in 2015 [33] affected Google searches for said disease. The countries that have increased and shown consistent interest throughout the examined period, i.e., that do not have many zeros, for either the English or the translated term, include Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, the Netherlands, Poland, Romania, Spain, Sweden, and the UK.

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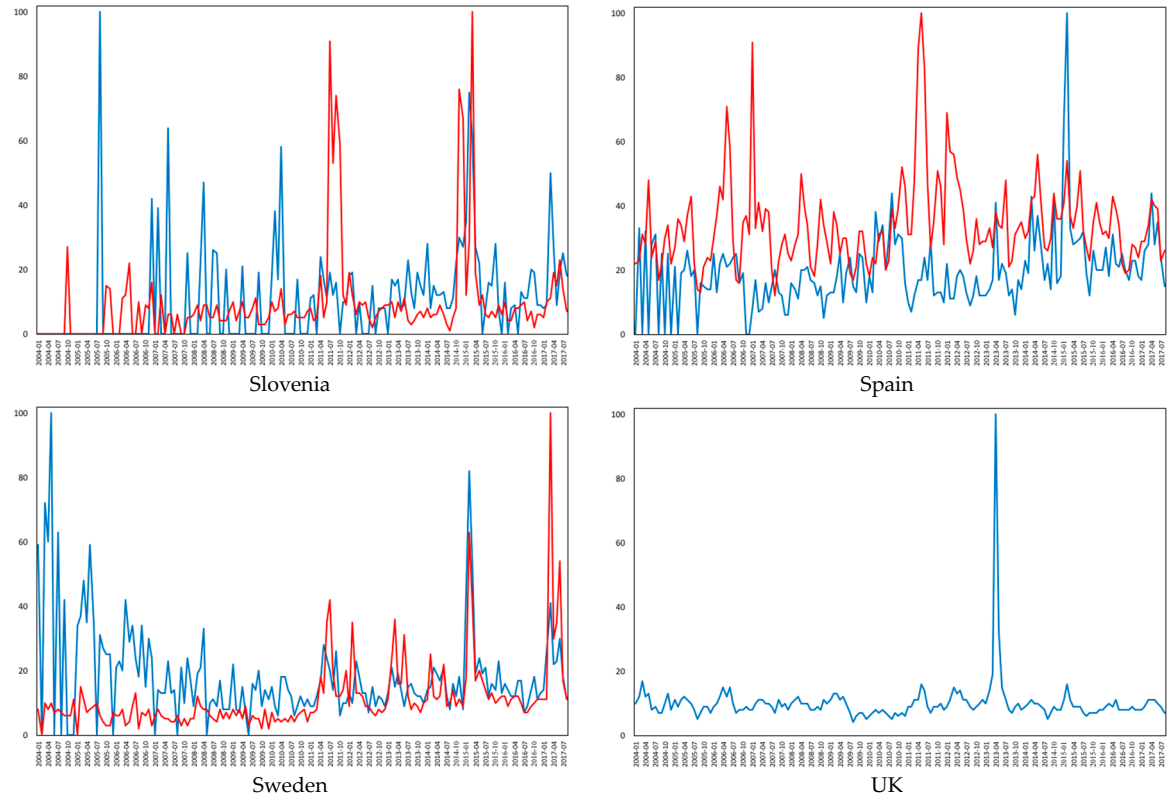

Figure 7. EU28 Online Interest in the English (blue) and Translated (red) Terms for 'Measles' from January 2004 to August 2017.

3.3. Measles EU Immunization Coverage

Figure 8 depicts the average of the population coverage percentages in the EU28 from 1980 to 2016 for the 1st dose of the Measles vaccine, and the average of the population coverage percentages for the 2nd dose of the Measles vaccine from 2000 to 2016. For the 1st dose, data for all EU28 countries from 1994 to 2017 are available, while datasets are not complete from 1980 to 1993. For the 2nd dose, data are only partly available for Belgium, Cyprus, Finland, France, Greece Italy, and Luxembourg, and no data are available for Ireland, while for the remaining EU28 countries full datasets are available.

The average percentage coverage has significantly increased since 1980, though it has experienced a drop in the past few years. The overall peaks in population coverage in Europe since 1980 are in 2013 and 2012 for the 1st and 2nd dose, respectively. In the EU28, the respective peaks are in 2013 and 2012. The percentages of the 2nd dose of the Measles vaccine in the EU28 are decreasing, even dropping below 90% in 2016. In order to be fully immunized, both doses of the Measles vaccine are required. As only 88.96% and 89.48% of the population in Europe and the EU28, respectively, are immunized, the current Measles outbreak can be explained, while the fear of an epidemic is justified.

Table 1 consists of the average percentage coverages of Europe and the EU28 for the 1st and the 2nd dose of the Measles vaccine from 2000 to 2016 [30].

Figures 9 and 10 map the EU28 population coverage for the Measles vaccine for the 1st and 2nd dose in 2016, respectively. Note that no data are available for Ireland for the 2nd dose.

For the 1st dose, Italy and Romania exhibit very low population coverage percentages, i.e., below 90%, while only 12 out of the 28 EU countries are above the 95% safety threshold. For the 2nd dose, the countries with the lowest immunization percentages in the Measles vaccine, i.e., less than 80%, are France and Romania, with Greece and Italy closely following similar attitude towards said vaccine, with immunization percentages of 83% in both countries. In the EU28, only Croatia, Hungary, and Slovakia are above the 95% safety threshold recommended by WHO.

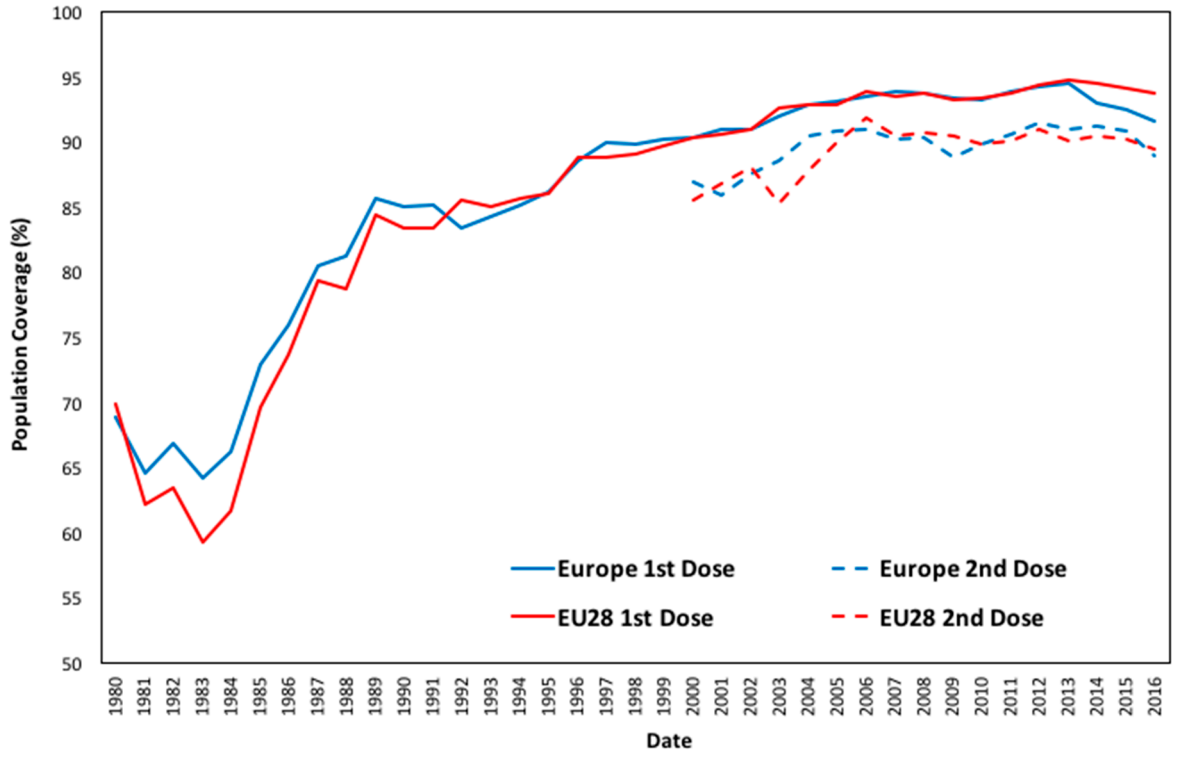

Figure 8. EU28 Population Coverage (%) of the 1st and 2nd Dose of the Vaccine for Measles from 1980 to 2016.

Table 1. Europe and EU28 Average Population Coverage Percentages (%) from 2000 to 2016.

Year	Europe 1st Dose	Europe 2nd Dose	EU 1st Dose	EU 2nd Dose
2000	90.40	87.00	90.43	85.57
2001	91.02	85.91	90.68	86.88
2002	91.04	87.62	91.07	88.11
2003	92.06	88.68	92.68	85.37
2004	92.87	90.51	92.89	87.85
2005	93.12	90.95	92.89	90.00
2006	93.51	91.02	93.93	91.86
2007	93.98	90.30	93.57	90.48
2008	93.77	90.45	93.75	90.74
2009	93.38	88.94	93.36	90.57
2010	93.28	89.83	93.39	89.88
2011	93.94	90.63	93.82	90.13
2012	94.34	91.48	94.50	91.08
2013	94.51	91.08	94.86	90.15
2014	93.06	91.30	94.61	90.46
2015	92.58	90.96	94.18	90.27
2016	91.64	88.96	93.86	89.48

France and Greece exhibit the highest rates of vaccine skepticism in the EU28, with Romania and Italy being in the 5th and 7th place, respectively [34]. As is depicted in Figure 10, these countries are the four countries with the lowest 2nd dose immunization percentages. Note that Romania poses a special case, where there are large populations of Romani people not being vaccinated, which was, however, the case in the past as well.

The EU countries are at an eminent risk of a Measles epidemic given the low immunization percentages and the high number of reported Measles cases, as has been supported by actions taken by several EU countries. For example, the Italian government has issued new legislation

making vaccination mandatory, with parents of unvaccinated children facing fines [35]. In Germany, kindergarten administrators have to report parents that refuse to be advised by doctors about vaccination [36], while Romania is preparing to issue a similar mandatory vaccination law [37].

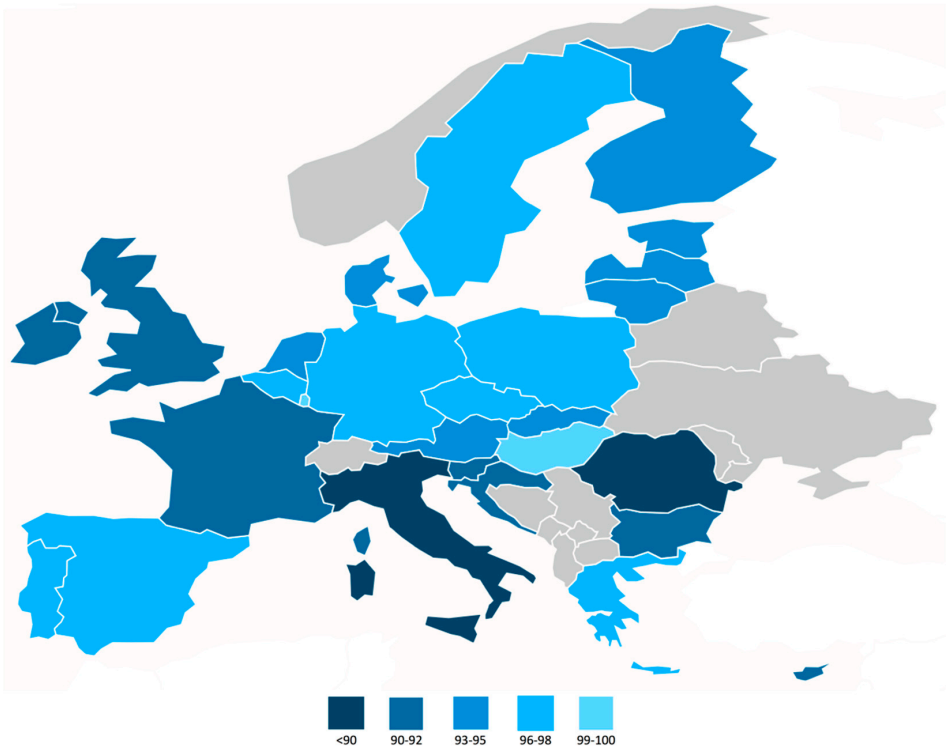

Figure 9. EU28 Population Coverage (%) for the 1st Dose in 2016.

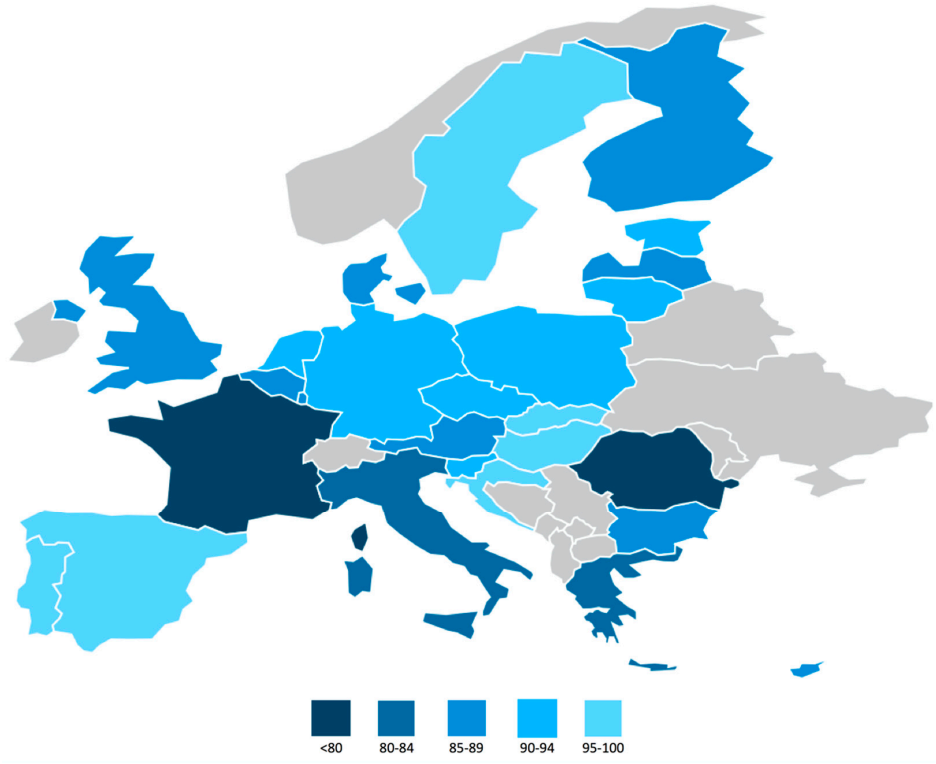

Figure 10. EU28 Population Coverage (%) for the 2nd Dose in 2016.

3.4. Confirmed EU Measles Cases

Table 2 consists of the total confirmed Measles cases from 2011 to (September) 2017 in the EU28 (by country code). In 2017, the countries with the most cases of Measles are Italy with 4204, followed by Romania with 3117, Germany with 796, Belgium with 359, and France with 352. Portugal, Hungary, Greece, Slovakia, Cyprus, and Luxembourg all had zero (0) cases in 2016, while they had several reported cases of Measles in 2017. Bulgaria had a high increase in reported cases (from 1 to 166), while Belgium and Czechia experienced significantly increased reporting of Measles cases, from 5 to 359 and from 7 to 134, respectively. Ireland, Lithuania, Poland, and the UK had significantly less reported Measles cases in 2017 compared to 2016, while Latvia and Malta had no cases in both 2016 and 2017.

Table 2. Total Confirmed Measles Cases in the EU28 from 2011 to 2017 [30].

Code	2011	2012	2013	2014	2015	2016	2017	Code	2011	2012	2013	2014	2015	2016	2017
AUT	219	35	79	119	300	28	80	ITA	5189	607	2256	3286	265	863	4204
BEL	1163	101	46	75	126	5	359	LVA	0	3	0	36	0	0	0
BGR	155	1	14	0	0	1	166	LTU	7	2	35	11	51	22	2
HRV	7	3	1	17	218	4	7	LUX	6	2	0	1	0	0	3
CYP	0	1	0	10	0	0	3	MLT	4	0	1	0	1	0	0
CZE	18	21	15	223	8	7	134	NLD	95	10	2640	144	7	6	11
DNK	84	2	17	29	9	3	1	POL	38	73	83	109	48	138	28
EST	7	4	2	0	4	2	1	PRT	2	7	1	0	0	0	34
FIN	29	4	2	2	1	5	5	ROU	4170	6164	1158	59	8	2432	3117
FRA	15,214	859	272	267	373	79	352	SVK	2	1	0	0	0	0	4
DEU	1600	167	1781	525	2383	328	796	SVN	22	2	1	52	19	1	6
GRC	40	3	2	1	1	0	11	ESP	3508	1210	131	153	55	38	141
HUN	0	1	1	0	0	0	25	SWE	26	31	51	26	22	3	24
IRL	193	104	51	35	13	43	12	GBR	1083	1903	1900	137	92	571	112

The 25% of the EU28 countries (7 in total) that score lowest in vaccination trust are France, Greece, Belgium, Romania, Slovenia, Bulgaria, and Italy [34]. All seven countries have reported increased cases of Measles in 2017 compared to 2016. At this point, it is interesting to note that all four countries in the EU28 that had a 2nd dose vaccination coverage in 2016 less than 85% (France, Romania, Italy, and Greece) are included in the list with the seven most vaccine-skeptical EU countries. The rest of the countries included in the list, namely Slovenia, Bulgaria, and Belgium, have a 2016 2nd dose population coverage of 93%, 88%, and 85%, respectively, all lower than the 95% safety threshold.

In order to explore the relationship between reported Measles cases and Google queries, the Pearson correlations for monthly data from January 2011 to August 2017 (N = 78) are calculated. For the respective translated terms, statistically significant positive correlations are observed for most of the EU28 countries, i.e., in Austria ($r = 0.4783$, $p < 0.01$), Belgium ($r = 0.5604$, $p < 0.01$), Croatia ($r = 0.65$, $p < 0.01$), Czechia ($r = 0.7410$, $p < 0.01$), Finland ($r = 0.7332$, $p < 0.01$), France ($r = 0.8908$, $p < 0.01$), Germany ($r = 0.5730$, $p < 0.01$), Italy ($r = 0.5555$, $p < 0.01$), Latvia ($r = 0.6253$, $p < 0.01$), Lithuania ($r = 0.6429$, $p < 0.01$), Netherlands ($r = 0.8725$, $p < 0.01$), Portugal ($r = 0.8508$, $p < 0.01$), Romania ($r = 0.4884$, $p < 0.01$), Slovakia ($r = 0.5997$, $p < 0.01$), Slovenia ($r = 0.5890$, $p < 0.01$), Spain ($r = 0.7734$, $p < 0.01$), Sweden ($r = 0.3459$, $p < 0.01$), Denmark ($r = 0.2418$, $p < 0.05$), Estonia ($r = 0.2433$, $p < 0.05$), Luxembourg ($r = 0.2553$, $p < 0.05$), and Hungary ($r = 0.2213$, $p < 0.10$).

Statistically significant positive correlations were also observed between the online interest in the English term and monthly reported Measels cases from January 2011 to August 2017 in several EU28 countries, namely in Austria ($r = 0.2594$, $p < 0.05$), Croatia ($r = 0.5825$, $p < 0.01$), Czechia ($r = 0.3112$, $p < 0.01$), Germany ($r = 0.5041$, $p < 0.01$), Ireland ($r = 0.3580$, $p < 0.01$), Italy ($r = 0.2368$, 0.05), Portugal ($r = 0.6211$, $p < 0.01$), Slovakia ($r = 0.2215$, $p < 0.10$), Slovenia ($r = 0.3348$, $p < 0.01$), and the UK ($r = 0.6307$, $p < 0.01$).

4. Discussion

This study's first aim was to track the 2017 EU Measles outbreak using online search traffic data from Google Trends. Given the rise of the Anti-Vaccine Movement over the past years that could be

attributed to false evidence that the MMR vaccine is associated with autism, the relations between Google queries related to anti vaccination and the recent outbreak in Measles are explored.

The results of this study suggest that there is a relation between the online interest in the Anti-Vaccine Movement and the decrease in vaccination percentages, and that the online queries for the term 'Measles' are potively correlated with Measles reported cases in most EU28 countries. Previous work has also suggested similar relationships between online data and reported cases of disease epidemics or outbreaks. Though this study considered data up to fall 2017, the serious issue of the EU Measles outbreak continues to exist and is showing increasing trends. In October 2017, the European Centre for Disease Prevention and Control stated that Measles could be further spread in Europe [38]. Greece faces a serious issue of Measles outbreak, with a total of 215 cases reported from 17 May 2017 to 1 October 2017 [38], while two children were admitted in the ICU with Measles-related complications [39]. Since the beginning of 2017, Italy has reported 4617 cases, four of which resulted to death, while in Romania, 34 deaths have been reported since January 2017 [38].

Measles require the highest immunization percentage compared to the other vaccine preventable diseases [9], and are one of the main causes of infant mortality that could have been vaccine-prevented [40]. The EU countries are facing an outbreak, which could result in an epidemic if the immunization percentages do not increase. Implications will also be evident from an economic point of view, as the treatment for Measles is higher than the cost of vaccination. Finally, other 'forgotten' diseases could soon resurface due to the Anti-Vaccine Movement, despite the scientists' and health officials' 'cry' for vaccination. As one to two out of 1000 diagnosed Measles cases in children result to death [41], in the case of an epidemic the casualties will be numerous.

As indicated by the results, online search traffic data could be proven a valid and valuable data source for governments and health officials for the monitoring of the behavior towards Measles and the Anti-Vaccine Movement. An interesting factor to be examined would be the degree of association of the Anti-Vaccine Movement with the overall recent political, social, and economic changes occurring in the EU at the moment. It has been suggested that advocacy and communication play a significant role in increasing Measles vaccination [8], while the measure of mandatory vaccinations is also considered or already enforced in several European countries [42]. However, governmental populism can negatively affect measures that should be taken in order to prevent disease spreading [43], while websites with available information on '*vaccine myths*' and anti-vaccination are more than the ones discussing the benefits of vaccination [44]. All the above add to the important factor influencing individuals to dismiss information about the positive effects of vaccines is that the communication of scientific issues is negatively affected by conspiracist ideation [7].

This study has some limitations. At first, the Measles outbreak practically occurred in 2017, with an increasing trend after September, which is out of this study's examined time-frame. Furthermore, the sample is not representative, as not all queries for the term 'Measles' correspond to reported cases and vice versa, and not all Anti-Vaccine searches correspond to not vaccinating and vice versa. Despite that, empirical correlations between Google Trends and official health data in various topics have been previously shown to exist. The 'Anti Vaccine' term is highly correlated ($p < 0.01$) with the Worldwide population coverage of the 2nd dose of the Measles vaccine; thus, future research on the subject could explore and further elaborate on the relationship between the Anti-Vaccine Movement and the decrease of the immunization percentages in Measles and other vaccine preventable diseases. Towards this direction, the relationships between the online interest in an extended list of English and translated terms related to the Anti-Vaccine Movement, the countries' immunization percentages, and reported cases of Measles, as well as other vaccine preventable diseases for individual countries, could be investigated.

The decrease in immunization percentages for Measles is a serious issue that negatively affects public health, while the impact could have been foreseen with the monitoring of the online behavior towards the Anti-Vaccine Movement over the last years. Exploring patterns of available information —that are related to population health as suggested by the science of infodemiology [45]—is increasingly

employed to effectively deal with topics related to public health. Epidemics and outbreaks may not exhibit seasonality, cycles, or long-term patterns, and thus the commonly used statistical tools and methods of analyzing seasonal diseases, such as asthma of the flu, may not be appropriate. Therefore, it is essential to effectively visualize these large amounts of data in order to explore and detect the trends and variations in interest over time, identify underlying patterns, and relate peaks to real-life events. This is highlighted by the results of this study that suggest that monitoring the changes in the online interest in selected terms could provide valuable information in behavioral variations and patterns. Said patterns could assist with the analysis of human behavior in public health issues, all the while providing health officials with valuable information to assess these issues and take preventive measures.

5. Conclusions

In the era of online information overload, can the use of the Internet affect public health? To address this question, this study aimed at tracking the 2017 EU Measles outbreak, by analyzing the online behavioral variations in terms related to Measles and the Anti-Vaccine Movement. The results suggest that statistically significant positive correlations exist between the monthly reported cases of Measles and the online interest in the respective translated term in most of the EU28 countries from January 2011 to August 2017. Furthermore, the term 'Anti Vaccine' is highly negatively correlated with the Worldwide immunization percentages from 2004 to 2016, i.e., as the online interest in the term 'Anti Vaccine' increases, the immunization percentages decrease.

This finding is supportive of previous research suggesting that conspiracist ideation is related to the rejection of science, as the negative relationship between online interest in the term 'Anti Vaccine' and the immunization percentages could be indicative of the role that the Internet plays in the spreading of false information, consequently affecting public health. In the case of Measles, the results are now starting to show, with reported Measles cases taking a sudden upturn over the past year in the EU, as immunization percentages (2nd dose) have significantly dropped since 2012—in most countries below the 95% safety threshold.

During the past few years, Big Data Analytics in general and the analysis of Internet behavior in specific have been shown to be effective at assessing various public health topics, as it has been suggested that patterns of available information are related to population health. Measles could be just the first of many to follow to exhibit such increase in reported cases, given that Measles require the highest immunization percentage out of the vaccine preventable diseases. Therefore, continuous monitoring is required for nowcasting the new cases that occur daily in relation to the variations in online interest, in order for the respective countries' Health Care Systems to be prepared, and for health officials to deal with reported cases in a timely manner and take the appropriate preventive measures, especially in countries and regions of high risk.

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