lek. Dominik Wawrzuta

Sentyment i opinie na temat szczepień w mediach społecznościowych: wielkoskalowa analiza tekstowa dyskursu internetowego

Vaccine Sentiment and Opinions on Social Media: A Large-Scale Textual Analysis of Online Discourse

Rozprawa doktorska na stopień doktora

w dziedzinie nauk medycznych i nauk o zdrowiu

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2. **Wawrzuta D**, Jaworski M, Gotlib J, Panczyk M. Social Media Sharing of Articles About Measles in a European Context: Text Analysis Study. J Med Internet Res. 2021 Nov 8;23(11):e30150. doi: 10.2196/30150.

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Spis treści

Wykaz zastosowanych skrótów

COVID-19	*ang. Coronavirus Disease 2019* – choroba koronawirusowa 2019
EMA	*ang. European Medicines Agency* – Europejska Agencja Leków
LDA	*ang. Latent Dirichlet Allocation* – Alokacja Ukrytego Dirichleta
NLP	*ang. natural language processing* – przetwarzanie języka naturalnego
NRC	*ang. National Research Council Canada* - Krajowa Rada ds. Badań Naukowych w Kanadzie
PRISMA	*ang. preferred reporting items for systematic reviews and meta-analyses* - preferowane pozycje sprawozdawcze do przeglądów systematycznych i metaanaliz
SARS-CoV-2	*ang. Severe Acute Respiratory Syndrome Coronavirus 2* – drugi koronawirus ciężkiego ostrego zespołu oddechowego
USD	*ang. United States dollar* – dolar amerykański
WHO	*ang. World Health Organization* – Światowa Organizacja Zdrowia

Streszczenie w języku polskim

Media społecznościowe są miejscem, w którym łatwo natrafić można na niesprawdzone lub nieprawdziwe informacje dotyczące tematów zdrowotnych. W ostatnich latach na platformach społecznościowych widoczna jest wzmożona aktywność przeciwników szczepień, którzy wykorzystują je do szerzenia dezinformacji. Rozproszona struktura sieci społecznościowych oraz bardzo duże ilości publikowanych tam informacji sprawiają, że niemożliwe jest śledzenie aktywności przeciwników szczepień oraz ich wpływu na społeczeństwo bez zastosowania nowoczesnych metod analitycznych z zakresu dużych zbiorów danych (*ang. big data*) oraz uczenia maszynowego (*ang. machine learning*). Pozyskane dzięki takim metodom informacje pozwalają na prowadzenie skutecznych akcji informacyjnych z zakresu zdrowia publicznego oraz na szybkie reagowanie na nowo powstałe nieprawdziwe komunikaty rozprzestrzeniane przez przeciwników szczepień.

Celem niniejszej dysertacji było zbadanie postaw użytkowników mediów społecznościowych w stosunku do szczepień ochronnych oraz opracowanie metodologii, dzięki której możliwe byłoby analizowanie ich zmienności w czasie. W ramach przeprowadzonych badań opisano cechy, którymi charakteryzują się informacje publikowane przez przeciwników szczepień w mediach społecznościowych oraz podjęto próbę określenia przyczyn ich szybkiego rozprzestrzeniania się. Dokonano również analizy cech opublikowanych w Europie, oraz udostępnionych w mediach społecznościowych, artykułów medialnych na temat odry, definiując czynniki które sprawiają, że niektóre materiały dziennikarskie cieszą się większą popularnością użytkowników mediów społecznościowych. Niniejszą dysertację zamykają wyniki badań prowadzonych w czasie pandemii COVID-19, które określiły i skategoryzowały postawy polskich użytkowników mediów społecznościowych wobec nowo powstałych szczepionek przeciwko SARS-CoV-2 oraz opisały zróżnicowanie postaw w zależności od używanej platformy społecznościowej.

Wyniki przeprowadzonych badań pokazują jak istotnym i szeroko rozpowszechnionym problemem jest obecna w mediach społecznościowych dezinformacja na temat szczepień. Jednocześnie udowadniają, że dzięki zastosowaniu metod statystycznych z zakresu przetwarzania języka naturalnego (*ang. natural language processing*) możliwe jest analizowanie dużych zbiorów danych tekstowych pochodzących z mediów społecznościowych. Pozwalają one na identyfikowanie aktualnych postaw użytkowników mediów społecznościowych oraz ich przekonań, a także predykowanie przyszłych zachowań na

podstawie historycznych danych. Zastosowanie przez instytucje związane ze zdrowiem publicznym opracowanych w ramach niniejszej dysertacji metod badawczych może pomóc w prowadzeniu monitoringu postaw społeczeństwa na temat szczepień oraz umożliwić planowanie precyzyjnych i skutecznych akcji edukacyjnych przeciwdziałających szerzeniu się dezinformacji.

Streszczenie w języku angielskim

Social media platforms have become a breeding ground for unverified and false information on health topics, including the dissemination of misinformation by anti-vaccinationists. The decentralized nature of social networks and the sheer volume of information shared there make it exceedingly challenging to track anti-vaccinationists' activities and societal impact without leveraging big data and machine learning analytics. Using such methods enables the acquisition of valuable insights, facilitating effective public health outreach and swift response to the proliferation of deceptive messages disseminated by vaccine opponents.

This dissertation aimed to examine social media users' attitudes toward immunization and develop a methodology for analyzing the temporal variations in these attitudes. The initial research characterized the information disseminated by opponents of vaccination on social media and ascertained the factors contributing to its rapid dissemination. Additionally, an analysis was conducted on media articles about measles published in Europe and shared on social media, identifying the elements that render certain journalistic materials more popular among social media users. Furthermore, this dissertation concludes with the findings of studies conducted during the COVID-19 pandemic, which examined the attitudes of Polish social media users towards the newly developed SARS-CoV-2 vaccines and delineated the variations in these attitudes based on the specific social media platforms employed.

The study results demonstrate the prevalence and significance of misinformation regarding vaccination circulating on social media. Concurrently, they establish that natural language processing (NLP) statistical methods make it feasible to analyze extensive sets of textual data derived from social media. This analytical approach enables the identification of current attitudes and beliefs held by social media users and the ability to predict future behaviors based on historical data. Adopting the research methods developed in this dissertation by public health institutions can facilitate the monitoring of public attitudes toward vaccination and facilitate the design of accurate and impactful educational campaigns to counter the dissemination of misinformation.

1. Wstęp

1.1. Znaczenie szczepień ochronnych dla zdrowia publicznego

Szczepienia ochronne są jednym z największych osiągnięć medycznych w dziejach ludzkości. Pierwszym dużym sukcesem wakcynologii było opracowanie w 1796 roku przez Edwarda Jennera szczepionki przeciwko ospie prawdziwej [1]. Dzięki jej zastosowaniu możliwe było całkowite wyeliminowanie tej śmiercionośnej choroby w roku 1980 [2]. Szczepienia ochronne umożliwiły również prawie całkowite wyeliminowanie zachorowań na polio. Dzięki zainicjowanej w 1988 roku przez Światową Organizację Zdrowia Globalnej Inicjatywie Eradykacji Polio, której celem jest zapewnienie ochrony szczepiennej przeciw polio wszystkim dzieciom na świecie, udało się ograniczyć o 99.9% liczbę zachorowań. Pozwoliło to na uratowanie życia 1 500 000 dzieci, a 16 000 000 uniknęło związanych z chorobą powikłań neurologicznych [3]. Szacuje się, że na całym świecie szczepienia ochronne pozwalają uniknąć około 3 000 000 śmierci rocznie [4]. Jednocześnie prowadzenie akcji szczepień ochronnych jest działaniem niezwykle skutecznym z ekonomicznego punktu widzenia. Dla przykładu każdy 1 USD zainwestowany w szczepienia przeciwko odrze w krajach rozwijających się generuje 58 USD oszczędności dla systemu ochrony zdrowia [5].

1.2. Działalność ruchów antyszczepionkowych

Pomimo udowodnionej skuteczności szczepień i powszechnego doświadczenia cierpienia niesionego przez choroby zakaźne, już w XIX wieku, tuż po upowszechnieniu się szczepionki przeciwko ospie prawdziwej, powstały pierwsze organizacje antyszczepionkowe. Ich aktywność szczególnie nasiliła się po wprowadzeniu w 1853 roku w Wielkiej Brytanii obowiązku szczepień przeciwko ospie prawdziwej wśród najmłodszych dzieci [6]. W XX wieku głośnym echem odbił się opublikowany w 1998 roku artykuł Andrew Wakefielda, w którym powiązał on przyczynowo szczepienia dzieci przeciwko odrze, śwince i różyczce z ryzykiem zachorowania na autyzm [7]. Pomimo iż jego twierdzenia okazały się fałszywe, a artykuł został wycofany (*ang. retracted*) po 12 latach przez redakcję czasopisma The Lancet [8], to zapoczątkowane przez niego nieprawdziwe twierdzenia obecne są do dziś w świadomości społecznej [9]. Obecnie argumenty podnoszone przez przeciwników szczepień są zróżnicowane i nie dotyczą jedynie zarzutów względem bezpieczeństwa lub skuteczności. Zwracają oni również uwagę na aspekty społeczne takie jak wolność osobista i nadużycia rządu w sytuacji wprowadzania obligatoryjności szczepień oraz promują niepotwierdzone naukowo metody leczenia, które uważają za alternatywę dla szczepień ochronnych [10].

1.3. Media społecznościowe jako źródło dezinformacji

Media społecznościowe uważane są za jeden z głównych obszarów działalności przeciwników szczepień [11]. Publikowane przez nich materiały często zawierają nieprawdziwe informacje lub promują teorie spiskowe [12]. Formułowane twierdzenia prezentowane są dodatkowo w sposób przyciągający uwagę pozostałych użytkowników mediów społecznościowych. W tym celu używają oni emocjonalnego języka oraz publikują treści opisujące osobiste doświadczenia, zamiast prezentowania neutralnych informacyjnych treści [12,13]. W efekcie antyszczepionkowy przekaz w mediach społecznościowych otrzymuje więcej pozytywnych reakcji użytkowników niż materiały zachęcające do szczepień [14,15].

Epidemia odry na Samoa w 2019 roku jest przykładem tego jakie efekty dla zdrowia publicznego może przynieść niekontrolowane szerzenie się dezinformacji na temat szczepień w mediach społecznościowych. W lipcu 2018 dwójka samoańskich dzieci zmarła po tym jak do przygotowania szczepionki przeciwko odrze, śwince i różyczce użyto przypadkowo roztworu kurary zamiast wody. W efekcie tego wydarzenia znacząco nasiliła się na Facebooku aktywność lokalnych działaczy antyszczepionkowych, co doprowadziło do znaczącego spadku wyszczepialności w społeczeństwie [16]. W efekcie już rok później odnotowano 5 000 zachorowań na odrę w tym liczącym 200 000 mieszkańców państwie, a 83 osoby zmarły z powodu infekcji [17]. Opanowanie epidemii stało się możliwe dopiero po aresztowaniu antyszczepionkowych aktywistów rozsiewających dezinformację na Facebooku oraz po przeprowadzeniu przez rząd powszechnej akcji szczepień przeciwko odrze [18].

2. Cele pracy

Cel główny:

Analiza treści dotyczących szczepień publikowanych przez użytkowników mediów społecznościowych (Facebook, Twitter, Instagram, TikTok) oraz opracowanie metod badawczych pozwalających na automatyczne analizowanie tworzonych przez nich komunikatów tekstowych z użyciem statystycznych metod przetwarzania języka naturalnego.

Pytania badawcze:

1. Dlaczego treści antyszczepionkowe szybko i łatwo rozprzestrzeniają się w mediach społecznościowych?
2. Czy w przypadku dziennikarskich artykułów medialnych dotyczących tematyki chorób zakaźnych można wyodrębnić charakterystyki, które sprawiają, że część z nich zyskuje duże zainteresowanie użytkowników mediów społecznościowych?
3. Czy pandemia COVID-19 i wprowadzenie na rynek nowych szczepionek przeciw SARS-CoV-2 spowodowały szerzenie się nowego typu treści antyszczepionkowych w mediach społecznościowych?
4. Czy możliwe jest opisanie różnorodnych argumentów antyszczepionkowych przy użyciu ograniczonej liczby ogólnych kategorii?
5. Czy na różnych platformach społecznościowych (Facebook, Twitter, Instagram, TikTok) pojawiają się różne typy argumentów przeciwko szczepieniom?

Hipotezy badawcze:

1. Ruchy antyszczepionkowe wykorzystują specyficzne metody komunikacji budzące zainteresowanie innych użytkowników mediów społecznościowych.
2. Możliwe jest wyodrębnienie cech dziennikarskich artykułów medialnych (na przykład poruszane tematy lub niesione emocje), które wpływają na zainteresowanie użytkowników mediów społecznościowych.
3. Opracowane w rekordowo szybkim tempie szczepionki przeciw SARS-CoV-2 przy zastosowaniu nowej technologii mRNA spowodowało powstanie nowych typów treści

przeciw szczepieniom związanych z tematyką niewystarczającego przetestowania nowej technologii.

4. Argumentacja ruchów antyszczepionkowych, pomimo dużej różnorodności, opiera się na ograniczonej grupie tematów, które używane są w różnych kontekstach.
5. Antyszczepionkowi użytkownicy używają różnych argumentów przeciwko szczepieniom w zależności od platformy społecznościowej z której korzystają.

Cele szczegółowe:

1. Określenie cech treści antyszczepionkowych publikowanych w mediach społecznościowych, które odpowiadają za ich szybkie rozpowszechnianie się oraz łatwość zdobywania popularności wśród użytkowników, która mierzona jest liczbą udostępnień i pozytywnych reakcji.
2. Określenie cech dziennikarskich artykułów medialnych (udostępnionych przez wydawców w mediach społecznościowych) poruszających tematykę chorób zakaźnych, które sprawiają, że poszczególne treści są chętniej niż inne udostępniane przez użytkowników mediów społecznościowych.
3. Określenie głównych wątpliwości polskich użytkowników mediów społecznościowych w stosunku do szczepień przeciw SARS-CoV-2. Identyfikacja nowych argumentów antyszczepionkowych nieużywanych w stosunku do wcześniej stosowanych szczepień.
4. Opracowanie słownika argumentów antyszczepionkowych, który umożliwi opisanie głównych kategorii tematów antyszczepionkowych, a w efekcie śledzenie ich dynamiki w czasie oraz badanie różnic ich popularności w różnych populacjach.
5. Analiza różnic w postawach wobec szczepień przeciw SARS-CoV-2 wśród polskich użytkowników popularnych platform społecznościowych – Facebook, Twitter, Instagram i TikTok.

3. Podstawy teoretyczne cyklu prac stanowiącego rozprawę doktorską

3.1. Popularność mediów społecznościowych w Europie

Szacuje się, że prawie 80% Europejczyków korzysta regularnie przynajmniej z jednej platformy społecznościowej [19]. W 2022 roku 40% Europejczyków jako źródła informacji używało Facebooka, 23% YouTube, 16% WhatsAppa, 14% Instagrama, 11% Facebook Messengera, 9% Twittera, 5% TikToka, a 4% Telegrama [20]. Poszczególne platformy różnią się typem treści publikowanych przez ich użytkowników. Na Facebooku przeważają treści tekstowe, często połączone ze zdjęciami lub treściami wideo. YouTube umożliwia zamieszczanie długich materiałów wideo. Instagram oparty jest w głównej mierze na materiałach audiowizualnych z przewagą zdjęć prezentujących codzienne życie użytkowników. Na TikToku publikowane są z kolei jedynie krótkie materiały wideo. Na Twitterze użytkownicy prezentują przede wszystkim krótkie wiadomości tekstowe. Z kolei WhatsApp, Facebook Messenger i Telegram skupiają się na umożliwianiu komunikacji pomiędzy użytkownikami. Typ prezentowanych treści oraz rok powstania platformy (Facebook – 2004 rok, YouTube – 2005 rok, Twitter – 2006 rok, WhatsApp – 2009 rok, Instagram – 2010 rok, Telegram – 2013 rok, TikTok – 2017 rok) w dużej mierze definiują cechy populacji korzystającej z poszczególnych platform społecznościowych.

3.2. Użytkownicy mediów społecznościowych

W zależności od grupy wiekowej różna jest preferowana przez użytkowników forma przyswajania treści informacyjnych dostępnych w mediach społecznościowych. W grupie wiekowej 35+ za najłatwiejsze w odbiorze uważane są w przede wszystkim wiadomości tekstowe. Wśród młodszych użytkowników również przeważa przywiązanie do treści tekstowych jednak u najmłodszych coraz częściej preferowane są materiały wizualne (zdjęcia i wideo), które uważane są przez nich za bardziej przyciągające uwagę [20]. Zależność tę potwierdzają statystyki użycia mediów społecznościowych w poszczególnych grupach wiekowych. Wśród użytkowników generacji Z (osoby urodzone w latach 1995 – 2012) szczególną popularnością cieszą się TikTok i Instagram, czyli platformy społecznościowe oparte na treściach audiowizualnych [21,22]. Z kolei w grupie wiekowej powyżej 45 roku życia najpopularniejsze są Facebook i WhatsApp, gdzie treści zawierają głównie informacje tekstowe [19]. Poszczególne grupy wiekowe poszukują różnych typów informacji w mediach

społecznościowych. Użytkownicy poniżej 35 roku życia częściej niż starsi zainteresowani są informacjami edukacyjnymi oraz wydarzeniami z życia celebrytów. Z kolei w grupie wiekowej powyżej 35 roku życia występuje większe zainteresowanie informacjami na temat lokalnych, międzynarodowych i politycznych wydarzeń [20]. Przeprowadzanie analiz treści opublikowanych w mediach społecznościowych wymaga uwzględnienia tych różnic w czasie planowania eksperymentów i wnioskowania statystycznego.

3.3. Rozprzestrzenianie się dezinformacji w mediach społecznościowych

Wraz ze wzrostem popularności mediów społecznościowych stały się one dla użytkowników miejscem uzyskiwania porad na temat zdrowia. Duże rozproszenie informacji tworzonych przez wielu niezweryfikowanych użytkowników, w większości niezwiązanych zawodowo z ochroną zdrowia, sprawiło jednak, że media społecznościowe stały się miejscem, gdzie łatwo szczerzy się dezinformacja (*ang. disinformation*) i misinformacja (*ang. misinformation*) na temat zagadnień dotyczących zdrowia. Misinformacja definiowana jest jako nieintencjonalne niedokładne lub błędne przekazanie faktów, podczas gdy z dezinformacją mamy do czynienia gdy twórca wie, że informacja nie jest prawdziwa i dochodzi do celowego wprowadzania odbiorców w błąd [23]. Najczęstszymi tematami, których dotyczą rozpowszechniane w mediach społecznościowych nieprawdziwe informacje medyczne są: szczepienia, palenie (w tym e-papierosów i marihuany), choroby niezakaźne (m.in. nowotwory, cukrzyca i padaczka), choroby zakaźne, dieta i zaburzenia odżywiania oraz tematyka terapii medycznych [24].

Media społecznościowe umożliwiają użytkownikom nie tylko tworzenie własnych treści, lecz również udostępnianie materiałów innych użytkowników, dzięki czemu możliwe jest szybkie rozprzestrzenianie się zarówno prawdziwych jak i fałszywych informacji [25,26]. Dotychczasowe badania wykazały, że najbardziej podatne na udostępnianie niesprawdzonych informacji w mediach społecznościowych są osoby, które ufają treściom napotkanym w internecie oraz które odczuwają konieczność nawiązywania kontaktów społecznych. Może wiązać się to z odczuwaniem lęku przed „wypadnięciem z obiegu" (*ang. fear of missing out*), który tworzy obawy, że interesujące wydarzenia mogą dziać się bez ich udziału [27,28]. W ostatnich latach, wraz z rozwojem sztucznej inteligencji, coraz większą rolę w rozprzestrzenianiu dezinformacji w mediach społecznościowych zaczynają pełnić automatyczne algorytmy takie jak na przykład boty, których aktywność często jest trudna do odróżnienia od aktywności ludzi [29,30]. Skuteczna walka z misinformacją i dezinformacją wymaga nie tylko określenia źródeł ich powstania, lecz również identyfikacji najbardziej podatnych na nie grup społecznych. Myślenie analityczne i zaufanie do nauki chronią przed

wiarą w nieprawdziwe informacje, podczas gdy myślenie konspiracyjne (*ang. conspiracy thinking*), religijność i konserwatywne poglądy polityczne są czynnikami zwiększającymi podatność na misinformację [31,32].

3.4. Wpływ mediów społecznościowych na postawy wobec szczepień

Rozpowszechnienie nieprawdziwych informacji w mediach społecznościowych jest uważane za jedną z głównych przyczyn niechęci wobec szczepień w społeczeństwie (*ang. vaccine hesitancy*) [33]. Może ona przyjmować różne postaci, począwszy od prób odraczania szczepień celem podania ich u dziecka w starszym wieku, poprzez całkowitą odmowę stosowania poszczególnych preparatów, aż po negatywny stosunek do wszystkich istniejących szczepionek [34]. Kontakt z nieprawdziwymi materiałami zniechęcającymi do szczepień bezpośrednio może przekładać się na decyzje dotyczące stosowania immunizacji [35]. Nawet niecałe 10 minut narażenia na opublikowane online treści antyszczepionkowe zwiększa poziom strachu i obniża świadomość ryzyka związanego z unikaniem szczepień [36]. Jest to szczególnie istotne biorąc pod uwagę, że media społecznościowe są jednym z głównych miejsc w których rodzice poszukują informacji na temat zdrowia swoich dzieci [37], a prawie połowa z nich deklaruje, że w mediach społecznościowych miała styczność z treściami antyszczepionkowymi [38]. Wykazanie nawet niewielkiego zainteresowania materiałami antyszczepionkowymi w mediach społecznościowych niesie dla użytkownika ryzyko wpadnięcia w bańkę informacyjną spowodowaną algorytmami platform społecznościowych. Przykładem takiego działania są algorytmy TikToka, które intensywnie promują nowe materiały podobne do treści dotychczas przeglądanych przez użytkownika. W efekcie obejrzenie zaledwie kilku filmów o treści antyszczepionkowej może spowodować automatyczne prezentowanie użytkownikowi wielu kolejnych podobnych materiałów przy jednoczesnym ograniczaniu dostępu do treści prezentujących inny punkt widzenia [39,40]. Efekty regularnej styczności z nieprawdziwymi informacjami opisane zostały już w 1977 i nazwane iluzorycznym efektem prawdy (*ang. illusory truth effect*) [41]. W efekcie powtarzającej się ekspozycji na nieprawdziwe informacje odbiorcy zaczynają postrzegać je jako znajome i w ostatecznie odbierać jako prawdziwe.

3.5. Aktywność ruchów antyszczepionkowych w czasie pandemii COVID-19

W czasie pandemii COVID-19 doszło do znacznego rozprzestrzenienia się dyskursu antyszczepionkowego w mediach społecznościowych [42]. Treści zniechęcające do szczepień szerzyły się bez wystarczającej kontroli ze strony platform społecznościowych [43]. W 2020 roku WHO ogłosiła, że sytuację informacyjną dotyczącą pandemii COVID-19 można nazwać stanem infodemii (*ang. infodemic*) [44]. Infodemia definiowana jest jako sytuacja, w której

dochodzi do nadmiernego rozprzestrzeniania się nieprawdziwych informacji dotyczących trwającej epidemii. Może ona prowadzić do dezorientacji społeczeństwa i podejmowania niekorzystnych działań zdrowotnych, a także do obniżenia zaufania do autorytetów medycznych, co utrudnia lub uniemożliwia skuteczne prowadzenie interwencji z zakresu zdrowia publicznego, a tym samym powoduje przedłużenie trwającej epidemii [45]. Tematy poruszane przez przeciwników szczepień w kontekście preparatów przeciw SARS-CoV-2 dotyczyły przede wszystkim dezinformacji na temat działań niepożądanych szczepień (m.in. toksyczności, powodowania bezpłodności lub trwałych zmian w DNA), zarzutów wobec procesu tworzenia szczepień (m.in. niewystarczających badań klinicznych, nieujawnionego rzeczywistego składu szczepionek) oraz teorii spiskowych (m.in. mikrochipów zawartych w szczepionkach lub celowego stworzenia wirusa SARS-CoV-2 celem depopulacji ludności) [46]. Analiza dezinformacji rozprzestrzeniającej się w czasie pandemii COVID-19 była szczególnie istotna ze względu na jej negatywny wpływ na wyszczepialność społeczeństwa, która była kluczowym elementem prowadzącym do opanowania pandemii [47].

4. Publikacje włączone do jednotematycznego cyklu prac

4.1. Struktura rozprawy doktorskiej

Rozprawę doktorską stanowi jednotematyczny cykl powiązanych tematycznie czterech publikacji. Trzy z nich są pracami oryginalnymi, a jeden artykuł jest przeglądem systematycznym. Przeprowadzone badania dotyczą oceny postaw użytkowników mediów społecznościowych wobec szczepień ochronnych. Dodatkowo w ramach prac badawczych podjęto próbę opracowania metodologii i zaleceń dotyczących realizowania analiz treści tekstowych na temat szczepień publikowanych w mediach społecznościowych. Badania prowadzone były w latach 2019 – 2022. W przypadku wszystkich wchodzących w skład cyklu prac jestem pierwszym autorem i jednocześnie autorem korespondencyjnym. Oświadczenia współautorów dołączono do niniejszej dysertacji.

4.2. Publikacja I

Wawrzuta D, Jaworski M, Gotlib J, Panczyk M. Characteristics of Antivaccine Messages on Social Media: Systematic Review. J Med Internet Res. 2021 Jun 4;23(6):e24564. doi: 10.2196/24564.

Wstęp

Nieprawdziwe informacje rozpowszechniane w mediach społecznościowych przez ruchy antyszczepienionkowe stanowią duże zagrożenie dla zdrowia publicznego. Treści zniechęcające do szczepień cieszą się popularnością nie tylko wśród zadeklarowanych przeciwników szczepień. Najczęściej ich odbiorcami są zwyczajni użytkownicy mediów społecznościowych. Zrozumienie przyczyn popularności treści antyszczepionkowych w mediach społecznościowych jest kluczowym krokiem na drodze ku stworzeniu efektywnych kampanii informacyjnych zwalczających dezinformację.

Cel

Celem badania było zebranie i zsyntetyzowanie w formie przeglądu systematycznego obecnego stanu wiedzy na temat aktywności ruchów antyszczepionkowych w mediach społecznościowych. Postawiono cztery szczegółowe hipotezy badawcze, które zweryfikować miał opracowany przegląd systematyczny:

1. Treści antyszczepionkowe w mediach społecznościowych otrzymują więcej pozytywnych reakcji niż proszczepionkowe.
2. Treści antyszczepionkowe są tworzone w sposób ułatwiający ich odbiór przez użytkowników mediów społecznościowych.
3. W dyskursie antyszczepionkowym szczepionki są przedstawiane jako niebezpieczne dla zdrowia lub nieskuteczne.
4. Przeciwnicy szczepień często opierają swoje twierdzenia na teoriach spiskowych lub niepotwierdzonych naukowo informacjach.

Materiały i metody

Przy użyciu wytycznych PRISMA przygotowano systematyczny przegląd anglojęzycznych artykułów opisujących badania na temat aktywności ruchów antyszczepionkowych w mediach społecznościowych. Do przeglądu włączone zostały publikacje dostępne w bazach danych Scopus, Web of Science i PubMed. Do analizy zakwalifikowano opublikowane w latach 2015 - 2019 artykuły naukowe badające treści antyszczepionkowe stworzone przez użytkowników mediów społecznościowych oraz analizujące je w sposób ilościowy lub jakościowy.

Wyniki

Po przeprowadzeniu analizy zgodnej z metodologią PRISMA do przeglądu systematycznego włączono 18 artykułów. Analizowały one treści antyszczepionkowe opublikowane na platformach YouTube, Twitter, Instagram lub Pinterest. 11 prac zajmowało się ogólną tematyką szczepień bez wyodrębniania szczegółowych preparatów, 5 artykułów badało postawy dotyczące szczepień przeciwko HPV, a 2 artykuły przeciwko odrze. Według większości badań antyszczepionkowe treści istotnie statystycznie częściej otrzymują pozytywne reakcje użytkowników niż treści promujące szczepienia. Jako jedną z przyczyn takiego stanu rzeczy zidentyfikowano fakt, że treści antyszczepionkowe tworzone są w sposób przyciągający uwagę odbiorcy. Często odnoszą się one do wydarzeń emocjonalnych, prezentujących historie pojedynczych osób, a ich twórcy używają nie tylko tekstu, lecz również materiałów wideo i zdjęć. Inną ujawnioną taktyką ruchów antyszczepionkowych jest zachęcanie celebrytów do udziału w materiałach medialnych, a także promowanie treści przy użyciu botów pierwotnie stworzonych do celów marketingowych. Analiza treści komunikatów antyszczepionkowych wykazała, że wyniki wszystkich dotychczasowych badań są zgodne co do podstawowych strategii komunikacyjnych ruchów antyszczepionkowych. W prowadzonym dyskursie nie poruszają one tematyki ochrony zapewnianej przez szczepienia, a skupiają się głównie na ich potencjalnej nieskuteczności i niebezpieczeństwach związanych ze stosowaniem. W celu podkreślenia fikcyjnych zagrożeń ruchy antyszczepionkowe często używają niepotwierdzonych naukowo informacji lub odnoszą się do teorii spiskowych.

Podsumowanie

Dzięki zastosowaniu nowoczesnych metod przekazu dostosowanych do potrzeb współczesnych odbiorców, treści antyszczepionkowe cieszą się dużą popularnością w mediach społecznościowych. Promowane przez nie twierdzenia są jednak oparte przede wszystkim na nieprawdziwych informacjach. Zrozumienie stosowanych przez ruchy antyszczepionkowe metod komunikacji i sposobów rozprzestrzeniania treści jest niezbędne w celu prowadzenia skutecznego ich monitoringu i planowania akcji edukacyjnych zdolnych do przezwyciężania dezinformacji.

4.3. Publikacja II

Wawrzuta D, Jaworski M, Gotlib J, Panczyk M. Social Media Sharing of Articles About Measles in a European Context: Text Analysis Study. J Med Internet Res. 2021 Nov 8;23(11):e30150. doi: 10.2196/30150.

Wstęp

Pomimo istnienia od 1963 roku skutecznej szczepionki, odra wciąż stanowi zagrożenie dla zdrowia i życia, ze względu na niewystarczającą wyszczepialność społeczeństwa. Sytuację pogarsza fakt, że w trakcie pandemii SARS-CoV-2 w wielu krajach odnotowano dodatkowy spadek zainteresowania przyjmowaniem szczepień przeciwko tej chorobie. Trudności w osiągnięciu odpowiedniego poziomu wyszczepialności wskazują na potrzebę opracowania skutecznych zasad prowadzenia akcji edukacyjno-informacyjnych z zakresu zdrowia publicznego. Szczególnie użyteczne w promowaniu szczepień przeciwko odrze mogą okazać się media społecznościowe. Publikowane tam odpowiednio przygotowane materiały edukacyjne mają szansę dotrzeć do dużej liczby odbiorców.

Cel

Celem badania była analiza artykułów na temat odry opublikowanych przez europejskie media i udostępnionych na platformach społecznościowych (Facebook, Twitter i Pinterest) w latach 2017-2019. W ramach badania określono główne tematy i sentyment opublikowanych artykułów, a następnie ustalono które z ich cech mają największy wpływ na popularność wśród użytkowników mediów społecznościowych.

Materiały i metody

W pierwszym etapie badania zidentyfikowano, pobrano i przetłumaczono na język angielski 10 305 artykułów na temat odry opublikowanych w latach 2017-2019 we wszystkich krajach Unii Europejskiej. Przy użyciu metody LDA (*ang. Latent Dirichlet Allocation)* określono główne tematy poruszane w analizowanych artykułach medialnych. Korzystając z narzędzia *NRC Word-Emotion Association Lexicon* oceniono emocje niesione przez każdy z artykułów.

Następnie przeprowadzono analizę wieloczynnikową przy użyciu regresji liniowej z wykorzystaniem powyższych zmiennych oraz dodatkowych danych socjodemograficznych dotyczących państw w których publikowane były artykuły. W ramach przeprowadzonej analizy określono cechy artykułów, których występowanie związane było z częstszym udostępnianiem ich przez użytkowników mediów społecznościowych (Facebooka, Twittera i Pinteresta).

Wyniki

Tematy występujące w artykułach medialnych na temat odry można podzielić na 3 główne kategorie: edukacyjne, dotyczące wydarzeń w Europie oraz odnoszące się do wydarzeń na świecie (poza Europą). W każdym z badanych państw większość publikowanych w mediach treści na temat odry skupiała się na lokalnych europejskich wydarzeniach, a niewielka część zawierała informacje edukacyjne lub poruszała tematykę światowych zakażeń wirusem odry. Analiza emocji niesionych przez artykuły ujawniła, że najczęstszymi emocjami wyrażanymi w artykułach były strach (przed chorobą) i zaufanie (do pomocy niesionej przez system ochrony zdrowia). Analiza wieloczynnikowa wykazała, że najchętniej udostępniane przez użytkowników mediów społeczności były artykuły zawierające informacje edukacyjne lub poruszające tematy dotyczące sytuacji epidemiologicznej w Niemczech, w Ukrainie, we Włoszech lub na Samoa. Wysoki poziom złości, radości i smutku zawartych w artykule również wiązał się z większą liczbą udostępnień.

Podsumowanie

Zarówno poruszana tematyka jak i emocje niesione przez artykuły medialne na temat odry mają wpływ na ich popularność w mediach społecznościowych i wynikającą z niej liczbę udostępnień artykułu. Zależności te mogą być wykorzystane w czasie prowadzenia akcji edukacyjnych zachęcających do szczepień przeciwko odrze. Tego typu treści powinny skupiać się na aspektach edukacyjnych i zawierać emocje, takie jak złość (skierowana na chorobę jako obiekt do zwalczenia), radość (z powodu bezpieczeństwa zapewnianego dzieciom przez szczepienia) lub smutek (w stosunku do cierpienia wywoływanego przez chorobę), aby dotrzeć do szerokiego grona odbiorców w mediach społecznościowych.

4.4. Publikacja III

Wawrzuta D, Jaworski M, Gotlib J, Panczyk M. What Arguments against COVID-19 Vaccines Run on Facebook in Poland: Content Analysis of Comments. Vaccines (Basel). 2021 May 10;9(5):481. doi: 10.3390/vaccines9050481.

Wstęp

Jeszcze przed rozpoczęciem akcji powszechnych szczepień ochronnych przeciw COVID-19 w mediach społecznościowych zaczęła szczerzyć się dezinformacja na temat nowo zarejestrowanych preparatów. Pomimo wysokiej śmiertelności i dużych kosztów społecznych związanych z przebiegiem COVID-19, ruchy antyszczepionkowe aktywnie prowadziły akcję mającą na celu zniechęcenie społeczeństwa do szczepień. Takie działania stanowiły duże zagrożenie dla powodzenia powszechnej akcji szczepień. Jednocześnie powstanie szczepionek mRNA spowodowało ujawnienie się nowych typów wątpliwości dotyczących bezpieczeństwa, które wcześniej nie były obecne w dyskursie antyszczepionkowym.

Cel

Celem badania było scharakteryzowanie argumentów przeciwko szczepieniom używanych przez polskich użytkowników Facebooka w okresie rejestracji nowych szczepionek przeciw COVID-19 (przed rozpoczęciem powszechnej akcji szczepień ochronnych). Przeanalizowano również zmienność sentymentu w czasie oraz typy reakcji użytkowników na napotykane w mediach społecznościowych antyszczepionkowe treści.

Materiały i metody

W badaniu przeanalizowano komentarze stworzone przez użytkowników Facebooka w odpowiedzi na materiały 14 najpopularniejszych polskich mediów (4 czasopism, 2 stacji radiowych, 5 internetowych serwisów informacyjnych i 3 stacji telewizyjnych), które opublikowane zostały na ich oficjalnych profilach na Facebooku. Analizowano treści związane z kluczowymi wydarzeniami prowadzącymi do wprowadzenia szczepionek przeciw COVID-19 na rynek: ogłoszenie skuteczności preparatu firmy Pfizer-BioNTech (09.11.2020), Moderna

(16.11.2020) i AstraZeneca (23.11.2020), rejestracja preparatu Pfizer-BioNTech przez EMA (21.12.2020) oraz podanie pierwszej dawki szczepionki w Polsce (27.12.2020). Następnie na podstawie dotychczasowej literatury i 1000 losowych komentarzy stworzono słownik (*ang. codebook*) najważniejszych argumentów stosowanych przez ruchy antyszczepionkowe w kontekście szczepień przeciw SARS-CoV-2. W ostatnim kroku wybrano 15% najpopularniejszych komentarzy z całego zbioru 22 791 komentarzy i oceniono ich tematykę przy użyciu wcześniej stworzonego słownika.

Wyniki

Antyszczepionkowe argumenty dotyczące preparatów przeciw COVID-19 można podzielić na 12 kategorii. Siedem z nich jest uniwersalnych i dotyczy także innych szczepionek, podczas gdy pozostałych pięć jest specyficznych dla preparatów chroniących przed COVID-19. Wszystkie kategorie przedstawiono je w Tabeli 1.

Tabela 1. Argumenty antyszczepionkowe dotyczące preparatów przeciw COVID-19 obecne w mediach społecznościowych przed rozpoczęciem powszechnej akcji szczepień

Temat	**Zastosowanie**
Brak zaufania do rządu	Uniwersalny
Szczepionki są niebezpieczne dla zdrowia	Uniwersalny
Choroba nie istnieje lub nie jest groźna	Uniwersalny
Nie chcę się szczepić z powodu wolności osobistej	Uniwersalny
Teorie konspiracyjne na temat szczepień	Uniwersalny
Szczepionki służą jedynie interesom korporacji	Uniwersalny
Naturalne metody leczenia są skuteczniejsze od szczepień	Uniwersalny
Nikt nie jest odpowiedzialny za działania niepożądane szczepień	Specyficzny dla COVID-19

Szczepionki przeciw SARS-CoV-2 nie istnieją lub nie są skuteczne	Specyficzny dla COVID-19
Szczepionki przeciw SARS-CoV-2 zostały stworzone już przed pandemią	Specyficzny dla COVID-19
Szczepionki przeciw SARS-CoV-2 nie zostały odpowiednio przetestowane	Specyficzny dla COVID-19
Przytaczanie historii zbyt szybkiego wprowadzenia na rynek szczepionki przeciw ptasiej grypie w 2009 roku	Specyficzny dla COVID-19

Najpopularniejszym argumentem podnoszonym przez polskich użytkowników Facebooka był brak zaufania do rządu, który odpowiedzialny był za organizację akcji szczepień. Jednocześnie w miarę upływu czasu (i bliskości rozpoczęcia akcji szczepień powszechnych) zwiększał się udział pozytywnych komentarzy na temat szczepień (z 7% na 22%), osiągając najwyższy poziom w momencie rozpoczęcia w Polsce akcji szczepień powszechnych. Z kolei zarejestrowanie preparatu Pfizer-BioNTech przez Europejską Agencję Leków (EMA) doprowadziło do znacznego spadku wątpliwości dotyczących odpowiedniego przetestowania nowych szczepionek. Należy również podkreślić, że o ile komentarze odnoszące się do informacji medialnych na temat szczepień były w zdecydowanej większości negatywne, o tyle jedynie niecałe 20% reakcji wyrażało negatywną postawę w stosunku do osiągnięć medycyny związanych z wprowadzaniem na rynek nowych szczepień.

Podsumowanie

Wyniki badania pozwoliły ustalić główne obawy i wątpliwości polskich użytkowników Facebooka na temat szczepionek przeciwko SARS-CoV-2. Wykazano, że wątpliwości wobec szczepień można podzielić na 12 różnych kategorii, których częstość występowania jest zmienna w czasie. Stworzony słownik tematów może być używany do regularnego monitoringu postaw wobec szczepień prezentowanych przez użytkowników mediów społecznościowych.

4.5. Publikacja IV

Wawrzuta D, Klejdysz J, Jaworski M, Gotlib J, Panczyk M. Attitudes toward COVID-19 Vaccination on Social Media: A Cross-Platform Analysis. Vaccines (Basel). 2022 Jul 27;10(8):1190. doi: 10.3390/vaccines10081190.

Wstęp

W czasie pandemii COVID-19 media społecznościowe stały się miejscem wzmożonej aktywności przeciwników szczepień. Obiektem ich ataków stały się zarówno nowo powstałe szczepionki mRNA, które krytykowane były przez nich jako niedostatecznie przebadane, jak również preparaty wektorowe, które obwiniali o powodowanie nadmiernie częstych działań niepożądanych. Dzięki prowadzonym w czasie pandemii analizom treści publikowanych w mediach społecznościowych możliwe było monitorowanie sentymentu antyszczepionkowego. W zdecydowanej większości badania te skupiały się jednak jedynie na pojedynczych platformach społecznościowych, nie biorąc pod uwagę szerszego kontekstu oraz zróżnicowania treści pomiędzy różnymi serwisami społecznościowymi.

Cel

Celem analizy było określenie argumentów używanych przez polskich przeciwników szczepień w stosunku do szczepionek przeciwko COVID-19 w czasie trwania powszechnej akcji szczepień, z uwzględnieniem różnic w dyskursie pomiędzy poszczególnymi platformami społecznościowymi (Facebook, Twitter, Instagram i TokTok).

Materiały i metody

Do badania włączono treści opublikowane pod hashtagiem #szczepimysie na platformach Facebook, Twitter, Instagram i TikTok od 1. sierpnia 2021 do 1. lutego 2022. Wybrany hashtag był popularnym miejscem dyskusji na temat szczepień przeciw COVID-19 na każdej z badanych platform, dzięki czemu możliwe było przeprowadzenie jednolitej analizy porównawczej treści. W ramach badania pobranych zostało 24 869 komentarzy z Facebooka, 8 721 z Twittera, 2 997 z Instagrama i 17 084 z TikToka, które opublikowane zostały w

odpowiedzi na posty udostępnione pod hashtagiem #szczepimysie. Następnie na podstawie dotychczasowej literatury i 100 losowych komentarzy określono główne kategorie tematów antyszczepionkowych oraz zakwalifikowano do tych kategorii po 250 najpopularniejszych komentarzy z każdej z analizowanych platform społecznościowych. Następnie wyznaczono słowa kluczowe dla każdej z kategorii metodą *relevance* [48] oraz oceniono podobieństwo częstości występowania poszczególnych typów komentarzy pomiędzy platformami społecznościowymi metodą *cosine similarity*.

Wyniki

W czasie pandemii polscy użytkownicy mediów społecznościowych używali 14 typów argumentów przeciw szczepieniom. Kategorie wraz z przypisanymi do nich słowami kluczowymi przedstawia Tabela 2. W stosunku do poprzedniego badania zrealizowanego w ramach dysertacji, które obejmowało sytuację przed rejestracją szczepień, ujawniono pojawienie się trzech nowych kategorii. Używający ich przeciwnicy szczepień twierdzili, że nie powinno się w mediach społecznościowych dzielić faktem przyjęcia szczepionki (gdyż jest to prywatne wydarzenie), że osoby zachęcające do szczepień robią to dla pieniędzy oraz że lepiej leczyć COVID-19 niż zapobiegać mu poprzez szczepienia.

Tabela 2. Argumenty antyszczepionkowe dotyczące preparatów przeciw COVID-19 obecne w mediach społecznościowych w czasie powszechnej akcji szczepień

Temat	**Słowa kluczowe**
Nie chcę się szczepić z powodu wolności osobistej	szczepienie, wybór, wolność, nigdy, przyjąć, każdy
Brak zaufania do rządu	ludzie, kłamać, prezent, nie więcej, Pinokio, propaganda
Szczepionki są niebezpieczne dla zdrowia	umierać, śmierć, ludzie, serce, otrzymać, komplikacje
Szczepionki nie są skuteczne	ochrona, dane, infekcja, dawka, z powodu, otrzymać

Szczepionki nie zostały odpowiednio przetestowane	eksperyment, test, medyczny, szczepionka, świnka morska
Krytyka chwalenia się przyjęciem szczepionki	przechwalać się, zrozumieć, reklamować, współczuć, publicznie, celebryta
Osoby publiczne tak naprawdę nie przyjmują szczepionek tylko obojętne substancje np. sól fizjologiczną	witaminy, sól fizjologiczna, strzykawka, placebo, telekonsultacja, zaszczepić
Teorie konspiracyjne na temat szczepień	normalność, pokrywać, dziwacy, ostrzeżenie, ofiara, bez precedensu
Osoba promująca szczepienia robi to dla korzyści finansowych	zapłacić, zdrajca, smród, dużo, reklama
COVID-19 nie jest groźny dla zdrowia	wirus, żywy, podobny, globalny, ewolucja, temat
Nikt nie jest odpowiedzialny za działania niepożądane szczepień	odpowiedzialność, najazd, skład, producent, odpowiedzialny, odszkodowanie
Szczepionki służą jedynie interesom korporacji	farmaceutyczny, wirusy, zainteresowany, dieta, szeroko, przychody
Lepiej leczyć COVID-19 niż mu zapobiegać	lek, amantadyna, stan, bałagan, autorytaryzm, leczenie
Naturalne metody leczenia są skuteczniejsze od szczepień	naturalny, wakcynofobia, cukier, wyleczony, kazanie, śmieci

Największym podobieństwem pod względem poruszanej tematyki charakteryzowały się platformy Facebook i Twitter, których użytkownicy poruszali przede wszystkim antyszczepionkowe argumenty związane z brakiem zaufania do rządu. Użytkownicy TikToka głównie skupiali się na zagadnieniach odebrania społeczeństwu wolności osobistej w kontekście decydowania o przyjmowaniu szczepień. Z kolei antyszczepionkowi użytkownicy Instagrama najczęściej zajmowali się krytykowaniem obecnych na platformie zwolenników

szczepień, którzy informowali publicznie o fakcie przyjęcia szczepionki i zachęcali do tego innych.

Podsumowanie

Niezależnie od używanej platformy przeciwnicy szczepień korzystają w mediach społecznościowych ze spójnego zestawu czternastu argumentów dotyczących szczepień przeciw COVID-19. Widoczne są jednak różnice popularności poszczególnych argumentów antyszczepionkowych pomiędzy poszczególnymi platformami. Z tego powodu akcje promujące szczepienia prowadzone w mediach społecznościowych powinny być dostosowane do poszczególnych grup odbiorców i prezentowanych przez nich wątpliwości oraz zarzutów wobec szczepień. Stworzony słownik tematów i powiązanych z nimi słów kluczowych może być używany w modelach statystycznych śledzących w czasie rzeczywistym sentyment wobec szczepień w mediach społecznościowych.

5. Podsumowanie

Przygotowany cykl jednotematycznych prac stanowi nie tylko usystematyzowany opis obecnych w mediach społecznościowych postaw wobec szczepień, lecz zawiera również praktyczne wskazówki ułatwiające zrozumienie źródeł antyszczepionkowych postaw użytkowników mediów społecznościowych, a tym samym umożliwia skuteczniejsze prowadzenie przez instytucje zajmujące się zdrowiem publicznym akcji edukacyjnych zachęcających do szczepień.

W ramach pierwszej publikacji stworzono przegląd systematyczny dotychczasowej literatury na temat aktywności ruchów antyszczepionkowych w mediach społecznościowych. Wykazano, że wiadomości antyszczepionkowe cieszą się w mediach społecznościowych większą popularnością niż treści promujące szczepienia. Ustalono również potencjalne przyczyny takiej sytuacji. Spowodowane jest to przede wszystkim tym, że treści antyszczepionkowe tworzone są w sposób przyjazny dla użytkowników mediów społecznościowych, często zawierają emocjonalne materiały graficzne oraz wideo, w niektórych przypadkach korzystając również z udziału celebrytów. Przeciwnicy szczepień używają także botów, dzięki którym są w stanie szeroko rozpowszechniać swoje materiały. Zastosowanie powyższych strategii komunikacji może pomóc w promocji treści zachęcających do szczepień, pozwalając na edukację osób do tej pory czerpiących informacje głównie ze źródeł antyszczepionkowych [49]

W ramach drugiej publikacji ustalono cechy artykułów na temat odry opublikowanych przez europejskie media i udostępnionych na platformach społecznościowych (Facebook, Twitter i Pinterest), które pozytywnie wpływają na ich popularność wśród użytkowników mediów społecznościowych. Na bazie ponad 10 000 artykułów medialnych wykazano, że najchętniej udostępniane przez użytkowników mediów społecznościowych są teksty zawierające treści edukacyjne oraz niosące ze sobą emocje, zarówno pozytywne, oparte na podkreślaniu ochrony zapewnianej przez szczepienia, jak i negatywne, zwracające uwagę na chorobę jako źródło cierpienia i zachęcające do podjęcia kroków celem jej zwalczania. Wyniki badania wskazują, że tworzenie edukacyjnych artykułów medialnych odpowiednio nacechowanych emocjonalnie może ułatwić ich promowanie w mediach społecznościowych, a przez to umożliwić prowadzenie skutecznych działań promujących szczepienia przy wykorzystaniu niewielkich zasobów finansowych przeznaczonych na działania marketingowe [50].

Trzecia i czwarta publikacja zrealizowane zostały w czasie pandemii COVID-19. Ich celem było przeanalizowanie sentymentu wobec szczepionek przeciw COVID-19, zarówno przed rozpoczęciem akcji powszechnych szczepień, jak i w jej trakcie. W ramach prac stworzono słownik argumentów używanych w mediach społecznościowych przez przeciwników szczepień w kontekście szczepionek przeciw COVID-19. Wykazano, że część z tematów była uniwersalna i używana także w odniesieniu do innych preparatów, z kolei inne powstały w czasie pandemii i były specyficzne dla nowych szczepionek przeciw COVID-19. Analizy wykazały również, że antyszczepionkowcy aktywnie zniechęcali do immunizacji jeszcze przed oficjalnym rozpoczęciem powszechnej akcji szczepień. Przeprowadzone w ramach dysertacji badania jako pierwsze na świecie porównały również sentyment wobec szczepień na czterech różnych platformach społecznościowych. Wykazano, że na Twitterze i Facebooku zarzuty wobec szczepień były podobne i dotyczyły głównie braku zaufania do rządu. Z kolei młodzi użytkownicy TikToka obawiali się przede wszystkim ograniczenia wolności osobistej, a antyszczepionkowi użytkownicy Instagrama skupiali się na dyskredytowaniu osób zachęcających do szczepień. Opracowane w ramach prac słowniki argumentów antyszczepionkowych pozwalają na śledzenie dynamiki postaw przeciwników szczepień oraz określanie głównych wątpliwości społeczeństwa wobec szczepień. Z kolei wykazanie różnic w postawach zależnie od używanej platformy społecznościowej pokazuje, że akcje promujące szczepienia powinny być tworzone z uwzględnieniem specyfiki użytkowników poszczególnych platform [51,52].

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7. Kopie opublikowanych prac

Review

Characteristics of Antivaccine Messages on Social Media: Systematic Review

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Abstract

Background: Supporters of the antivaccination movement can easily spread information that is not scientifically proven on social media. Therefore, learning more about their posts and activities is instrumental in effectively reacting and responding to the false information they publish, which is aimed at discouraging people from taking vaccines.

Objective: This study aims to gather, assess, and synthesize evidence related to the current state of knowledge about antivaccine social media users' web-based activities.

Methods: We systematically reviewed English-language papers from 3 databases (Scopus, Web of Science, and PubMed). A data extraction form was established, which included authors, year of publication, specific objectives, study design, comparison, and outcomes of significance. We performed an aggregative narrative synthesis of the included studies.

Results: The search strategy retrieved 731 records in total. After screening for duplicates and eligibility, 18 articles were included in the qualitative synthesis. Although most of the authors analyzed text messages, some of them studied images or videos. In addition, although most of the studies examined vaccines in general, 5 focused specifically on human papillomavirus vaccines, 2 on measles vaccines, and 1 on influenza vaccines. The synthesized studies dealt with the popularity of provaccination and antivaccination content, the style and manner in which messages about vaccines were formulated for the users, a range of topics concerning vaccines (harmful action, limited freedom of choice, and conspiracy theories), and the role and activity of bots in the dissemination of these messages in social media.

Conclusions: Proponents of the antivaccine movement use a limited number of arguments in their messages; therefore, it is possible to prepare publications clarifying doubts and debunking the most common lies. Public health authorities should continuously monitor social media to quickly find new antivaccine arguments and then create information campaigns for both health professionals and other users.

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KEYWORDS

vaccination; social media; antivaccination movement; vaccination refusal; health communication; public health; vaccines

Introduction

Background

From the time of its inception, the internet has provided supporters of the antivaccine movement with unprecedented possibilities to affect societies by nearly global communication of their opinions and convictions. The internet has immense potential as a medium for disseminating health information. However, this information can be unreferenced, incomplete, or informal, and thus, it can be considered dangerous [1-5]. The antivaccination messages on the internet are far more unbridled than in other media. For this reason, the internet is a source that can lead to the risk of people making uninformed decisions about vaccination [6]. Contemporary social media is regarded

as a major communication tool for spreading information about the antivaccination movement [7,8].

Early studies concerning the content shared on antivaccination websites revealed that this thematic area includes 3 main issues: concerns about vaccine safety and effectiveness, concerns about governmental abuses, and a preference for alternative health practices [2,6,9,10]. First, a key aspect is the perceived risk of severe and long-term side effects of vaccinating a child. Second, mandatory vaccinations are perceived as an unacceptable breach of the right to make independent decisions and as a limitation of civil liberties. A mistrust also exists that is expressed through the belief that governmental supervision bodies keep the reports about the adverse reactions associated with vaccinations a secret and collaborate with the pharmaceutical industry to profit from vaccine sales. Third, alternative health practices are promoted as being more natural than conventional medicine, and they are believed to eliminate the need for vaccination once they are properly followed.

The majority of the antivaccine arguments evoke negative emotions such as fear [8]. In contrast, many provaccine arguments and campaigns are grounded in the values of harm and fairness [11]. Furthermore, the moral ideas of purity and liberty are mostly associated with vaccine hesitancy. The people for whom these values are of great significance will be insensitive to the information on the positive aspects of vaccinations [12]. Most of the arguments used by antivaccination activists can be perceived as part of a broader phenomenon called denialism. Denialism can be defined as "the employment of rhetorical arguments to give the appearance of a legitimate debate where there is none, an approach that has the ultimate goal of rejecting a proposition on which a scientific consensus exists" [13]. The European Center for Disease Prevention and Control defines vaccine hesitancy as a "delay in acceptance or refusal of vaccines despite availability of vaccination services" [14]. Such a delay results from broader influences and should always be considered in the historical, political, and sociocultural contexts in which vaccinations occur [15-17]. According to the World Health Organization, vaccine hesitancy is a continuum with the people who are unsure about vaccines or want to delay only some vaccinations being on one end and people who refuse all vaccines being on the other [18].

The spread of negative information about vaccination on the internet and social media is considered to be the leading cause of vaccine hesitancy [17]. Many studies have revealed the negative impact of media controversies related to vaccination safety on the level of vaccination coverage [19,20]. The ubiquitous presence of antivaccination content on the World Wide Web contributes to the prompt dissemination of rumors, myths, and false opinions about vaccines, which subsequently lowers vaccination coverage [4,10,21]. The results of a study by Betsch et al [22] revealed that reading antivaccination webpages for even approximately 5-10 minutes negatively affects the perception of the risk related to vaccination. Dube et al [23] and Smith et al [24] made similar observations. Glanz et al [7] emphasized that exposure to antivaccine messages through social media may intensify parents' worries and change their intention to vaccinate their children.

Web 2.0 functions (such as those in Facebook, Twitter, YouTube, and blogs and discussion groups) enable users to develop and share content; thus, users can easily and quickly share their personal experiences related to vaccination [21,25]. In this context, social media has become a platform where intimate and emotionally loaded information is exchanged [26]. Here, one can also find the support of people with similar health problems or doubts [27]. Some studies have revealed that content related to vaccines can be found in all social media and that the critical content generally correlated with the content previously published on an antivaccination websites [28,29]. Several important claims on social media may have promoted this phenomenon, including claims that social media is a big business and is powerful, that the audience is poorly defined, that fairness is irrelevant, and that nothing is truly private [30]. These factors may affect people's decisions concerning treatment and preventive health care, including preventive vaccination.

Searching for health information on social media has become increasingly popular [26,31]. Analyses revealed that 41% of parents found antivaccination content through social media [32]. Nearly 16% of all internet users look for information about vaccinations, and 70% of them confirmed that the information they had found affected their decisions [33]. Evrony and Caplan [8] emphasized the need for a more effective search and criticism of the false information on vaccination published on the internet. They highlighted that although every internet user has a choice, spreading disinformation and distorting the facts concerning vaccines is not a choice. Such activities should be noted and effectively challenged. Therefore, it is crucial to learn not only about antivaccine information but also about its emotional load and to identify the content addressees. Such a thorough analysis will help to better understand the motivations and emotions that accompany the information created by antivaccinationists.

Currently, the literature is limited to review articles on the potential role of social media in influencing vaccination beliefs and behavior [10,21,33]. Despite the growing number of papers studying the content published by supporters of the antivaccination movement in social media in recent years, no systematic review analyzing these papers has been developed so far. Previous literature reviews have analyzed disinformation concerning health on social media [34] and health information shared on YouTube [35]. They tackled the issue of vaccination and antivaccination movements only on a fragmented basis, as part of a broader topic. Catalan-Matamoros and Peñafiel-Saiz [36] published a systematic review investigating the communication about vaccinations in traditional media, excluding the content shared on the internet and social media. Considering the activity of the antivaccination movement's supporters on social media and how easily they can communicate their messages that are not scientifically confirmed to a large number of recipients, it is crucial to learn and understand their activities and messages. This knowledge will help us react and respond effectively to the false information they publish.

Objectives

This study aims to gather, assess, and synthesize evidence regarding the current state of knowledge about antivaccine social media users' web-based activities. We checked 4 general hypotheses about the features of antivaccine content on social media that are often described in papers in the field of vaccinology:

1. Antivaccine messages are more liked and shared than provaccine content.
2. Antivaccine content is more user friendly than provaccine content.
3. Antivaccine social media users describe vaccines as harmful for health or ineffective.
4. Antivaccine social media users share conspiracy theories or claims that are not scientifically proven.

In addition, we summarized the current knowledge on the role of social media bots in the spread of antivaccine messages.

Methods

Design

We designed a systematic review that systematically searched, appraised, and synthesized research evidence following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines [37].

Eligibility Criteria

We included papers based on the following inclusion criteria:

1. Papers based only on original studies.
2. Papers analyzing the user-generated content available on social media platforms (including Twitter, Facebook, Instagram, Pinterest, YouTube, LinkedIn, TikTok, Snapchat, VKontakte, WhatsApp, WeChat, Tumblr, Qzone, Reddit, and Sina Weibo).
3. Papers in which the authors extracted a group of antivaccine messages and conducted analyses that contained both qualitative and quantitative elements.

The exclusion criteria were as follows:

1. Papers not written in English.
2. Papers in which vaccines were not the main topic of research.
3. Methodological papers.
4. Conference abstracts.

Information Sources and Search Strategies

Our search strategy was guided by the following research question: What are the existing data about antivaccine users' activity on social media? We conducted a scoping literature search of papers published between January 1, 2015, and December 31, 2019, on 3 databases (Scopus, Web of Science, and PubMed), taking into account the PRISMA guidelines. Overall, 2 reviewers (DW and MP) independently screened the databases using the same protocol. The search was conducted in January 2020. We chose the last 5 years for two reasons. First, in 2014, the social media market began to resemble the one known today. The growth of the major platform Facebook slowed, but the activity of users increased. Furthermore, smaller platforms such as Twitter, Instagram, Pinterest, and LinkedIn gained popularity [38]. Second, from our abstract analysis, we found no articles published in 2014 that were potentially eligible for this systematic review; this suggests that the number of papers analyzing negative messages on social media started to grow in 2015.

The query used in the search engines of the databases is as follows:

(("social media" OR "Twitter" OR "Facebook" OR "Instagram" OR "Pinterest" OR "YouTube" OR "LinkedIn" OR "TikTok" OR "Snapchat" OR "VKontakte" OR

"WhatsApp" OR "WeChat" OR "Tumblr" OR "Qzone" OR "Reddit" OR "Sina Weibo")

AND

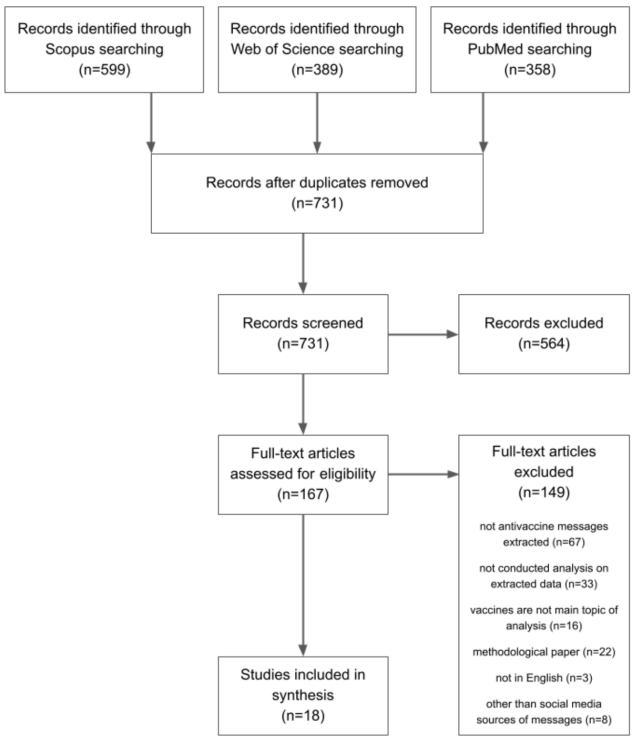
("vaccin*" OR "immuni*"))

We also searched the reference lists of the previously retrieved studies and literature reviews.

Study Selection

A 3-stage approach was used to include and exclude studies in the final review process. Initially, duplicate studies were excluded; subsequently, a screening was performed based on the (1) title, (2) abstract, and finally, (3) full text. Discrepancies regarding article selection were resolved by a consensus within the reviewing team (Figure 1).

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram.



Data Collection Process, Extraction, and Quality Assessment

We found 599 articles from Scopus, 389 from Web of Science, and 358 from PubMed. After removing duplicates, 731 articles were analyzed further. In the next step, the titles, abstracts, and keywords were screened. At this stage, we removed papers dealing with pharmacovigilance on social media, survey research, theoretical mathematical models, interventions in social media to increase vaccination coverage, and descriptive analysis without the messages being extracted. Two researchers (DW and MP) conducted a full-text analysis of the remaining 167 papers. A data extraction form was established, and it included authors, year of publication, country, specific objectives, study design, social media platform, type of data analyzed, number of messages studied, main objectives and findings, and geographic focus. Standardized checklist tools were not used to assess the quality and risk of bias of individual studies.

Synthesis of the Results

The outcomes of the 18 studies included in the final analysis were heterogeneous. We performed an aggregative narrative synthesis of the included studies.

Results

Studies' Characteristics

The number of articles analyzing antivaccination messages on social media has increased over the last 5 years. This topic became highly popular in 2019, during which 7 of the 18 included papers were published. Overall, 7 of the 18 papers studied Twitter. YouTube was slightly less popular and was analyzed 6 times. The remaining articles studied Facebook, Instagram, and Pinterest. Although most of the authors analyzed text messages, some of them studied images or videos. The number of analyzed messages varied from 123 to 1,793,690 across the papers. The oldest messages were published in 2006. Table 1 describes the general characteristics of the included studies.

Table 1. Characteristics of the included studies.

Study	Platform	Type of data	Number of messages	Geographic focus	Main topic	Time interval
Basch and MacLean (2019) [39]	Instagram	Text, image	150	English language	HPV[a]	2018
Blankenship et al (2018) [40]	Twitter	Text	1626	English language	Not specified	2014-2015
Broniatowski et al (2018) [41]	Twitter	Text	1,793,690	English language	Not specified	2014-2017
Covolo et al (2017) [42]	YouTube	Video	123	Italian language	Not specified	2014-2015
Donzelli et al (2018) [43]	YouTube	Video	560	Italian language	Not specified	2007-2017
Ekram et al (2019) [44]	YouTube	Text, video	35 videos with comments	English language	HPV	2014
Faasse et al (2016) [45]	Facebook	Text	1489	English language	Not specified	2016
Guidry et al (2015) [46]	Pinterest	Images	800	English language	Not specified	2014
Harvey et al (2019) [47]	Facebook	Meme	234	English language	Not specified	Not specified
Kang et al (2017) [48]	Twitter	Text	26,389	United States	Not specified	2015
Kearney et al (2019) [49]	Instagram	Text, image, video	360	English language	HPV	2011-2018
Luo et al (2019) [50]	Twitter	Text	287,100	English language	HPV	2008-2017
Massey et al (2016) [51]	Twitter	Text	193,379	English language	HPV	2014-2015
Mitra et al (2016) [52]	Twitter	Text	315,240	English language	Not specified	2012-2015
Song and Gruzd (2017) [53]	YouTube	Video	1984	English language	Not specified	Not specified
Venkatraman et al (2015) [54]	YouTube	Video	175	English language	Not specified	Not specified
Yiannakoulias et al (2019) [55]	YouTube	Video	275	English language	Influenza, measles	2006-2018
Yuan et al (2019) [56]	Twitter	Text	669,136	English language	Measles	2015

[a]HPV: human papillomavirus.

There are differences in the methods used to extract the messages. Most of the authors searched for general vaccine-related queries [41,42,46-48,52] or the content of tags [40]. Papers analyzing the human papillomavirus (HPV) vaccine used both general terms (such as HPV, HPV vaccine, #HPV, and #HPVvaccine) [39,44,49-51] and specific vaccine names (Gardasil and Cervarix) [49,51]. Polarized opinions, both positive and negative, were isolated using phrases containing words connected to vaccination and autism [43,53,54]. As Facebook does not allow for searching of posts using a search engine, the authors analyzing this platform used more sophisticated methods to extract messages. Faasse et al [45] studied responses to a photograph that promoted vaccination and was published by Facebook CEO Mark Zuckerberg. Harvey et al [47] found 128 Facebook fan pages devoted to vaccination and sampled up to 30 memes from each page. The papers included content analyzed at different time intervals (Table 1). Only 1 study used search criteria specifically related to the outbreak of an infectious disease. Yuan et al [56] used Twitter data from February 1 to March 9, 2015, to study the tweets published just after the measles outbreak in Disneyland, California, in 2015.

Although most studies examined vaccines in general, 5 focused specifically on HPV vaccines, 2 on measles, and 1 on influenza. Among the articles examining negative comments about the HPV vaccine, 2 examined Twitter, 2 Instagram, and 1 YouTube. These HPV-related messages mention the side effects and risks associated with vaccination [50,51] but often omit some information [44]. Furthermore, HPV-related antivaccine messages on Instagram used more sophisticated forms of communication, including videos or text with images [49]. Provaccine content describing the HPV vaccine contained information on protection against and prevention of cancer [39,50,51] and the safety of the vaccine [44].

In Table 2, we have aggregated the research questions of the included studies into 4 general hypotheses. In the next paragraphs, we describe the results of the analyzed articles in terms of these hypotheses and we discuss bots' activities on social media.

Table 2. Results of the included studies.

Study	Hypothesis 1: Antivaccine messages are more liked and shared than provaccine content	Hypothesis 2: Antivaccine users share more user-friendly content than provaccine users	Hypothesis 3: Antivaccine users describe vaccines as harmful for health	Hypothesis 4: Antivaccine users share conspiracy theories or claims that are not scientifically proven
Basch and MacLean (2019) [39]	Antivaccine messages have more likes than provaccine content (P=.02)	N/A[a]	Antivaccine users are less likely to mention the protection provided by the HPV[b] vaccine (P<.001)	N/A
Blankenship et al (2018) [40]	Antivaccine messages have more retweets than provaccine ones (P<.001)	Most shared antivaccine-related URLs link to Twitter, YouTube, and Facebook	N/A	N/A
Broniatowski et al (2018) [41]	N/A	Content polluters, which may have been primarily created for marketing, spread more antivaccine content than the average nonbot users (P<.001)	N/A	N/A
Covolo et al (2017) [42]	Antivaccine messages are more liked (P<.001) and shared (P<.001) but are less viewed (P<.001) than provaccine content	N/A	Fear-related themes are present more often in the antivaccine content than in the provaccine one. However, the difference is not statistically significant (P>.05)	Antivaccine content is less likely to have been developed by health professionals than provaccine contents (P=.002)
Donzelli et al (2018) [43]	Antivaccine messages have more likes, shares, and views (P<.001) than provaccine content	Antivaccine content is mainly represented in the categories "People & Blogs" and "No-profit and activism"	N/A	N/A
Ekram et al (2019) [44]	There is no difference between anti- and provaccine content in the number of likes and views (P>.05)	N/A	Antivaccine users are more likely to exclude information about vaccine safety (P<.05) and efficacy (P<.05)	Antivaccine users are more likely to report incorrectly (P<.001) or omit information (P<.01)
Faasse et al (2016) [45]	Antivaccine comments have fewer likes than provaccine comments (P<.001)	Antivaccine content uses more analytical thinking (P<.001) and less tentative language (P=.055)	Antivaccine users use more words related to health (P<.001) and money (P=.03)	N/A
Guidry et al (2015) [46]	N/A	Antivaccine users use more narrative than statistical information (P<.001)	N/A	27.7% of the antivaccine content mentions conspiracy theories
Harvey et al (2019) [47]	Antivaccine messages get more reactions (P<.001) and shares (P<.001) than provaccine content	Antivaccine content has stronger emotional appeal (P<.001)	Antivaccine content appeals more to fear (P<.001) and more often uses themes connecting vaccines with injuries, safety issues, and autism (P<.001)	Antivaccine content contains a greater percentage of false statements (P<.001) and more often mentions conspiracy theories (P<.01)
Kang et al (2017) [48]	N/A	Antivaccine content addresses a broader range of topics compared with provaccine content	Central concepts are thimerosal, mercury, autism, flu shots, and vaccine ingredients	Central concepts are CDC[c], the vaccine industry, mainstream media, doctors, mandatory vaccines, and pharmaceutical companies
Kearney et al (2019) [49]	Antivaccine messages are more liked (P<.001) than provaccine ones	Antivaccine content uses more personal narratives than informational ones (P<.001). Videos or text with images are more often used rather than text or images alone (P<.001)	N/A	Antivaccine content is less likely to have been created by health-related users (P<.001)
Luo et al (2019) [50]	N/A	N/A	Antivaccine users more often use words such as "death," "concern," "kill," "injured," "safety," "adverse," "scandal," and "fraud"	N/A

Study	Hypothesis 1: Antivaccine messages are more liked and shared than provaccine content	Hypothesis 2: Antivaccine users share more user-friendly content than provaccine users	Hypothesis 3: Antivaccine users describe vaccines as harmful for health	Hypothesis 4: Antivaccine users share conspiracy theories or claims that are not scientifically proven
Massey et al (2016) [51]	Negative messages have fewer retweets than provaccine ones do but are still more than neutral (P<.001)	N/A	Antivaccine users more often mention side effects (P<.001) and are less likely to discuss the protection provided by HPV vaccine (P<.001)	N/A
Mitra et al (2016) [52]	N/A	More direct (P<.05) and certain language (P<.05) is used in antivaccine content	Antivaccine users more often discuss death concerns (P<.001)	The "evil government" topic is often discussed (P<.001)
Song and Gruzd (2017) [53]	Antivaccine messages have a higher like-to-dislike ratio (P=.001)	Antivaccine content is easier to access through YouTube recommendations (centrality measures P<0.01). It is more likely to be found in the categories "People & Blogs" and "News & Politics" (P<.005)	N/A	N/A
Venkatraman et al (2015) [54]	No difference was noted in terms of likes (P=.86) and views (P=.38) between anti- and provaccine content	Antivaccine users more often use celebrities in videos (P=.07)	Antivaccine users are more likely to use personal stories to indicate the negative effects caused by vaccinations (P<.001)	The links provided by antivaccine users less often lead to scientific articles (P=.01)
Yiannakoulias et al (2019) [55]	Antivaccine content is more liked than provaccine content is	N/A	Antivaccine content has higher frequency of the words "mercury," "syringe," "chemical," and "toxic"	N/A
Yuan et al (2019) [56]	N/A	Antivaccine users prefer to communicate with users of the same opinion group	N/A	N/A

[a]N/A: not applicable.

[b]HPV: human papillomavirus.

[c]CDC: US Centers for Disease Control and Prevention.

Hypothesis 1: Popularity of Content

The authors used different measures to estimate the popularity of antivaccine content. These measures depended on the characteristics of the platforms. Each platform allows researchers to assess user engagement in response to the content. They measured retweets on Twitter [40,51]; likes and shares on Facebook [45,47]; likes on Instagram [39,49]; and likes, dislikes, or shares on YouTube [42-44,53-55]. In addition, YouTube allows for the measurement of audience size by providing information about the number of views, which was also analyzed in a few papers [42-44,54]. In our data set, 12 studies evaluated whether antivaccine content is more popular on social media than provaccine content. Overall, 8 of them found that antivaccine content was more popular, 2 did not find a difference in popularity, and 2 found that provaccine messages were more popular. The popularity of user-generated content depends on the type of platform and can be expressed by likes, reactions, shares, retweets, or views. On Instagram, antivaccine messages had more likes than provaccine messages [39,49]. YouTube videos with negative vaccine sentiments were more appreciated by users (they had more likes, shares, or views) [42,43,53,55]. However, 2 studies did not find statistically significant differences in the number of likes and views between provaccine and antivaccine YouTube videos [44,54]. The analysis of Twitter content did not show a clear link between sentiment and popularity. Blankenship et al [40] found that antivaccine messages had more retweets than provaccine messages, whereas Massey et al [51] found the opposite. The results of the study on Facebook content were similarly ambiguous. Harvey et al [47] found that antivaccine memes had more likes and shares, whereas Faasse et al [45] showed that provaccine Facebook comments had more likes. The results suggest that although antivaccine messages are generally more popular on social media, platform-dependent differences may exist.

Hypothesis 2: User-friendly Content

Antivaccine users present content in a way that tends to be user friendly: it grabs the users' attention and encourages them to read the posts. Various methods are used to ensure this. The messages contain personal narratives or stories [46,49,54] and are connected with strong emotions and fear [42,47,52]. The language used is also different. Antivaccine articles use phrases such as mandated vaccines and adverse effects, whereas provaccine articles use required vaccines and side effects [48]. The language of antivaccine content is direct and certain [52] not tentative [45]. This content is rarely created by health professionals [42,49] but is well suited to the web-based environment as it uses videos or text with images rather than text or images alone [49]. Antivaccine videos also feature celebrities more often than provaccine videos do [54]. On

YouTube, negative videos are mainly presented in lifestyle categories such as People & Blogs [43,53]. All results show that antivaccine users create their messages in a way that effectively grabs the attention of their audience.

Hypothesis 3: Vaccines Are Unhealthy or Do Not Work

Antivaccine users often describe vaccinations as harmful to health. They connect them with serious but scientifically unconfirmed injuries, safety issues, and side effects such as autism or even death [44,47,51,54]. They refer to the use of toxic ingredients in vaccines, including mercury and thimerosal [48,55].

Antivaccine messages try to create the impression that vaccines do not protect against diseases. Not only do they present false information about vaccines [47] but they also tend to omit information about the safety and protection provided by vaccines [39,44,51]. All papers indicated that antivaccine users try to create an impression that vaccines are ineffective and dangerous to health.

Hypothesis 4: Vaccines Are a Part of a Conspiracy

In the antivaccine discourse, vaccines are often described as part of conspiracy theories [44,46,47]. Antivaccine concepts are linked to the Centers for Disease Control and Prevention, the Food and Drug Administration, and the pharmaceutical industry hiding the truth about vaccines' side effects or a government using vaccines to obtain control over society or to perform eugenic actions [45,48,50,52]. Antivaccine users view mandatory vaccines as a threat to their civil liberties [46,47]. They believe that as vaccinations carry risks, patients' informed consent is necessary.

Bots' Activity

Using automated tools to spread vaccine-related information can be an efficient and effective way of convincing social media users. A total of 77% of the bots active on Twitter are provaccine. They are hypersocial in retweeting, and they mainly retweet from their opinion group [56]. Research on the activity of bots and trolls in a vaccine debate on Twitter showed that content polluters, which may have been primarily created for marketing, share antivaccine messages at a higher rate than average nonbot users do. Russian trolls post vaccine content at a higher rate than nonbot users do, but they share an equal number of provaccine and antivaccine messages because their purpose is to promote discord in the vaccination debate [41].

Discussion

Principal Findings

Regardless of the social media platform, there are similarities in the characteristics of antivaccine content. Most of the authors found that vaccine-related messages with negative sentiments had a higher number of positive reactions on social media (likes, shares, and retweets). This relationship was particularly evident on YouTube and Instagram, whereas the results from the studies on Twitter and Facebook were inconclusive. The reason for this ambiguity in the case of Facebook may lie in the sampling of the analyzed messages. Harvey et al [47] studied the popularity of memes published on 128 Facebook pages devoted to vaccinations and found that antivaccine messages received more reactions than provaccine messages. Faasse et al [45] obtained the opposite results after studying the comments posted in response to the photo uploaded by Mark Zuckerberg to promote vaccines. However, the percentage of provaccine users constituting Mark Zuckerberg's profile followers may be higher than the percentage of provaccine users in the entire population. On Twitter, Massey et al [51] found that negative messages have fewer retweets than positive ones, but this study was limited to HPV-related tweets. Future research should investigate the popularity of antivaccine content on Twitter and Facebook. The high number of likes on and shares of antivaccine content poses the danger that ordinary users will find this information more easily and consider it to be more reliable than provaccine messages.

We also found that antivaccine users create messages in a user-friendly manner. They publish emotional personal stories using direct language. Their content is not created by health professionals, and they publish more often in the categories under lifestyle than in those connected with medicine or science. Psychological studies have shown that emotional events are remembered more accurately and for a longer time than neutral events [57]. Thus, the emotional communication of antivaccine content may have contributed to the effectiveness of the antivaccine movement. Antivaccine activists often use methods that are commonly used in marketing. Emotional stories attract the attention of neutral users [58], whereas the stirring up of fear of vaccinations leads to the inaction of the audience [59].

The proponents of the antivaccine movement call vaccines dangerous for health and ineffective. The myth-busting research pointing to vaccine safety [60,61] is not stopping the spread of false information. Some people do not trust science, considering it as a tool in the hands of governments and pharmaceutical companies [62]. Many parents believe that the risks of vaccination outweigh its benefits [63]. In countries where parents do not see children dying from infectious diseases, it is easy to think that vaccines, and not the diseases they protect against, are the problem. This phenomenon is perhaps being magnified by the fact that fear-related sources automatically attract attention [64].

Antivaccine messages often contain conspiracy theories. Previous research indicates that a belief in at least one conspiracy theory is common in society [65]. Contrary to popular opinion, conspiracism is not a product of ignorance; it can be explained by the human willingness to believe in the unseen. In a study conducted by Jolley and Douglas [62], participants who were exposed to antivaccine conspiracy theories showed less intention to vaccinate than the control group. Education can help solve this problem because preexisting knowledge about vaccination may protect against the negative effects of exposure to vaccine-related conspiracy theories on the web [66]. Only a simple debunking of misinformation can strengthen its persistence in the community [67] or even increase the harmful activity of conspiracists [68]. Clarifying parental concerns and involving parents in decisions regarding their child's vaccination can reduce beliefs in conspiracies [69].

The analyzed papers show that bots on social media spread not only antivaccine messages but also provaccine messages. The literature differentiates between benign and malicious bots [70]. Benign bots respond automatically, aggregate content, and perform other useful actions. However, malicious bots are designed with a purpose to harm. Their task is to manipulate, mislead, and exploit to influence social media discourse. Public health authorities should not only monitor social media, detect negative bots, and fight the spread of the antivaccine content, but they should also use benign bots to communicate with the public and dispel doubts about vaccinations.

The results of the included papers are generally consistent with those of previous research examining antivaccine website content [2,6,9,10]. Similar to websites, antivaccine users of social media raise and discuss concerns about the safety and effectiveness of vaccines. They describe vaccines as harmful for health, present scientifically unconfirmed claims, and hide information about the safety and effectiveness of vaccines to strengthen their messages. This behavior can be explained by a well-known cognitive phenomenon called motivated reasoning, which is defined as a tendency to find arguments in favor of the conclusions we believe in, rather than those supporting what we do not want to believe in [71]. Both antivaccine websites and antivaccine social media users presented two arguments concerning the government. They believe that the government is cooperating with pharmaceutical corporations to impose universal immunization programs and is allowing these companies to profit. The second argument does not suggest evil government plans but points to the restriction of freedom of choice because of mandatory vaccines. Unlike the content of antivaccine websites, negative posts on social media do not promote alternative health practices; they simply discourage vaccinations. This may be because short and eye-catching content is preferred on social media, and this does not allow for the explanation or discussion of complex issues.

We found that most included studies were based on Twitter data. This is surprising because Facebook, YouTube, and Instagram have many more active users [72]. The reason for this disproportionate attention may lie in the simplicity of gathering data from Twitter. Twitter enables the downloading of thousands of posts using its official application programming interface [73], whereas Facebook and Instagram closed their application programming interfaces in 2018, thus preventing the automatic downloading of publicly available data from these platforms to protect users' data against inappropriate use [74]. This was in response to the Cambridge Analytica data misuse scandal [75]. Moreover, Facebook allows for the creation of closed and private groups whose content is not available to scientists. YouTube provides researchers with easy access to the content by providing automatically generated transcripts of videos, thus facilitating text analysis. Since 2019, Pinterest has been hosting vaccine-related information only from reliable sources to halt the spread of vaccine misinformation [76]; therefore, further research into the antivaccine user's activity on this platform since 2019 is pointless.

Web-based platforms differ in terms of how easily the antivaccine content is spread through social media. Facebook and Instagram have taken steps to stop the spread of vaccine misinformation by making it less prominent in search results; however, such misinformation has not been completely removed from these platforms [77]. Recent research shows that since 2016, interactions with content containing misinformation have reduced on Facebook but have continued to increase on Twitter [78]. This suggests that misinformation on Twitter can become a bigger problem than on Facebook. During the COVID-19 pandemic in 2020, Twitter started removing accounts spreading health conspiracy theories [79] and tried to redirect users searching for COVID-19–related information to official government sources [80].

YouTube facilitates the spread of misinformation to millions of viewers. It has been found that 27.5% of the most-viewed YouTube videos related to COVID-19 contained misinformation, and these reached over 62 million viewers worldwide [81]. About 17 million people subscribe to antivaccine accounts on YouTube [82]. As YouTube content is more difficult to create, it is probably less affected by bots sharing video content. However, bots can spread disinformation on YouTube through comments [83].

In the papers studied, the HPV vaccine was the second most common topic, after the topic of vaccines in general. This topic is popular in the discourse on antivaccine movements. The HPV vaccine has some specific features that make it vulnerable to theories that discourage vaccinations. First, in many countries, this vaccine is not mandatory; therefore, it can be more effectively discouraged. Second, the minimum age for receiving the first dose is 9 years; thus, often both parents' consent and the preteen or teenager's acceptance are required. Finally, apart from the ordinary antivaccination supporters, the HPV vaccine has other opponents. Conservative religious groups suggest that protection against sexually transmitted diseases encourages licentious teen sex. As a result, religious young women are undervaccinated and underinformed about the HPV vaccine [84].

Future Research Propositions

Research conducted in languages other than English is limited. In our data set, only 2 articles analyzed non-English messages, which were in Italian [42,43]. We propose that a multilingual comparative study be undertaken to explore the similarities and differences in the vaccine-related discourse on social media between countries.

Another issue is the classification of messages as provaccine or antivaccine. Usually, this task is performed manually using codebooks. As this method is not scalable, we need to employ an automatic approach. Popularly, some of the messages are hand-labeled using a codebook, and machine learning models are applied to label the rest of the messages. We suggest that a universal codebook or dictionary be designed to assess whether a message has antivaccine sentiment. Such a tool would enhance the comparability of the research results.

Instagram is a social media platform that is still gaining popularity not only among users but also among scientists, as shown by the 2 articles from 2019 [39,49] that we included in our systematic review. However, previous Instagram studies have only examined opinions regarding HPV vaccines.

Analyzing data from private or secret Facebook groups [85] is important, as they often contain valuable information about users' opinions and attitudes toward vaccinations. Although messages posted in such groups potentially contain higher quality information than publicly available data, they are not easy to obtain.

It should also be mentioned that the articles analyzed picture antivaccine messages related to specific words, phrases, and themes. Further research on these topics can result in the creation of effective tools to automatically detect fake news. This can help suppress vaccine hesitancy, which is connected to the spread of vaccine misinformation on social media [86].

Limitations

First, we restricted the analysis to studies published between 2015 and 2019. As a result, some papers describing antivaccine messages on social media may not have been included. Second, we studied only articles written in English. Thus, we may have omitted articles published in other languages that analyzed non-English messages on social media.

Conclusions

Antivaccine users create content that gains more positive reactions (likes, shares, retweets) on social media than provaccine messages do. Their messages are user friendly and well suited to the needs of users on social media platforms. Antivaccine users try to discourage vaccination using a few main arguments. They describe vaccines as harmful, highlight their side effects, and undermine the effectiveness of the protection they offer. To support these statements, they use false information and conspiracy theories, and gloss over or omit the data about vaccine benefits.

Public health authorities should continuously monitor social media to find new antivaccine arguments quickly and, based on that, design information campaigns targeting health professionals and ordinary users who are at a risk of being misinformed. Social media platforms have a big responsibility because they give millions of users access to misinformation. Knowledge of the characteristics of antivaccine content can help in the creation of tools that automatically tag false information. A positive trend in recent years is that social media platforms have attempted to stop the spread of vaccination misinformation.

Conflicts of Interest

None declared.

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Abbreviations

HPV: human papillomavirus

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses

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Original Paper

Social Media Sharing of Articles About Measles in a European Context: Text Analysis Study

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Abstract

Background: Despite the existence of an effective vaccine, measles still threatens the health and lives of many Europeans. Notably, during the COVID-19 pandemic, measles vaccine uptake declined; as a result, after the pandemic, European countries will have to increase vaccination rates to restore the extent of vaccination coverage among the population. Because information obtained from social media are one of the main causes of vaccine hesitancy, knowledge of the nature of information pertaining to measles that is shared on social media may help create educational campaigns.

Objective: In this study, we aim to define the characteristics of European news about measles shared on social media platforms (ie, Facebook, Twitter, and Pinterest) from 2017 to 2019.

Methods: We downloaded and translated (into English) 10,305 articles on measles published in European Union countries. Using latent Dirichlet allocation, we identified main topics and estimated the sentiments expressed in these articles. Furthermore, we used linear regression to determine factors related to the number of times a given article was shared on social media.

Results: We found that, in most European social media posts, measles is only discussed in the context of local European events. Articles containing educational information and describing world outbreaks appeared less frequently. The most common emotions identified from the study's news data set were fear and trust. Yet, it was found that readers were more likely to share information on educational topics and the situation in Germany, Ukraine, Italy, and Samoa. A high amount of anger, joy, and sadness expressed within the text was also associated with a higher number of shares.

Conclusions: We identified which features of news articles were related to increased social media shares. We found that social media users prefer sharing educational news to sharing informational news. Appropriate emotional content can also increase the willingness of social media users to share an article. Effective media content that promotes measles vaccinations should contain educational or scientific information, as well as specific emotions (such as anger, joy, or sadness). Articles with this type of content may offer the best chance of disseminating vital messages to a broad social media audience.

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KEYWORDS

measles; Facebook; Twitter; Pinterest; social media; vaccine; infodemiology; public health

Introduction

Background

The first measles vaccine was approved in 1963. Before the invention of this vaccine, measles caused 6 million deaths annually [1]. Since use of this vaccine became common, the number of measles cases worldwide has started to decline. A few years after the first vaccination campaign, the number of new measles cases plunged to one-twentieth of the previous figure [2]. In some countries, the cases of measles have been eliminated almost completely, although local epidemics still occur from time to time [3].

Despite the proven effectiveness of vaccination in saving millions of lives annually, some individuals have questioned the safety and long-term benefits of vaccine use. In 1998, Andrew Wakefield, a British physician and academic, published an article connecting the measles, mumps, and rubella (MMR) vaccine to autism among children [4]. This paper was retracted 12 years later; however, antivaccine activists still argue against vaccination. Antivaccination movements are one of the main obstacles for public health professionals in conducting vaccination campaigns. Vaccine hesitancy is a significant problem as only a high measles vaccination coverage—of about 95%—can enable the complete eradication of this disease. Currently, global vaccination coverage against measles is approximately 70%. Measles vaccines protect not only human lives but also the economies of low- and middle-income countries, generating US $58 for an investment of US $1 [5].

One example of the result of the decline in measles vaccination coverage was the outbreak in Samoa. In September 2019, in Samoa, a country with a small population of 200,000, a measles outbreak led to over 5000 infections and 83 deaths [6]. The reason behind the outbreak was the suspension of the country's immunization program by the Samoan government in July 2018 following the death of 2 children as a result of nurses' inadvertent use of curare muscle relaxant anesthetic instead of water to dilute the MMR vaccine. This led to a decrease in measles vaccination coverage in Samoa to 31% by the end of 2019 [7]. After multiple measles-related deaths, the authorities decided to organize a vaccination campaign. Approximately 95% of eligible people in Samoa were vaccinated against measles, which put an end to the outbreak [8]. This case shows how quickly the measles virus can spread when a vaccination program is suspended. Therefore, it is important to constantly monitor measles epidemiology and people's attitudes toward it to promptly prevent vaccine hesitancy.

This problem surrounding vaccination coverage has also been observed in Europe. The European Centre for Disease Prevention and Control (ECDC) data suggests that the second dose of MMR vaccine coverage is over 95% in only 5 European Union countries. This extent of coverage can ensure the immunity of the population against this disease and eliminate the chance of an outbreak [9]. In the European Union, the number of measles cases declined in 2020—mainly caused by the COVID-19 pandemic and the result of wearing masks, practicing social distancing, and conducting social lockdowns [10]—except for Romania and Bulgaria. In 2020, there were over 20 measles cases per million inhabitants in these 2 countries [11]. After the COVID-19 pandemic ends, European societies will probably notice an increase in measles morbidity as there was a decline in measles vaccine administration among children during the lockdowns [12]. Moreover, Europeans have been using social media more frequently during the COVID-19 pandemic. This may result in the growth of negative attitudes in the public toward vaccination as exposure to disinformation on social media increases vaccine hesitancy [13,14]. As social media contribute significantly, analyzing social media content and the activities of users can help better understand public attitudes and opinions regarding measles. The knowledge gathered from this analysis will inform the actions to increase MMR vaccine coverage and prevent the spread of misinformation.

Study Aim

We aim to characterize European measles news reports shared on social media platforms (ie, Facebook, Twitter, and Pinterest) during 2017 to 2019 (ie, the pre–COVID-19 period). For this purpose, we formulated the following 3 research questions: (1) What are the main topics of the articles on measles published in the European Union countries? (2) What sentiments are associated with these news articles? (3) Which features of the articles are associated with an increased number of shares on social media?

Methods

Data Collection and Preparation

We collected articles on measles that were shared on Facebook, Twitter, or Pinterest from 28 European Union countries.

First, we translated the word "measles" into all 23 official languages of the European Union using Wiktionary [15] and used a social media data analysis platform (ahrefs, Ahrefs Pte. Ltd [16]), which continuously collects, processes, and stores information from social media platforms about users' content and activities, to collect news articles. For each European Union country, we downloaded all articles on measles published from January 1, 2017, to December 31, 2019. We chose this time range because there was a significant increase in the number of measles infections in Europe in 2017 that lasted until the start of the COVID-19 pandemic [17]. We selected articles containing the word "measles" in the national language and published on websites with national domains (eg, ".de" domain for Germany, ".pl" for Poland). Our data set contained the URL of the article, the publication date, and the number of shares (ie, the total number of shares for all instances of the article) on Facebook, Twitter, and Pinterest.

As the next step, we obtained the full text of the articles (n=12,638) and read the content. To accomplish this task, we used a Python newspaper package (version 0.3.0) [18] that allows an automated download of the website content.

We automatically translated all non-English articles into English using Yandex Translate [19]. Finally, we removed all duplicate articles and those that had been improperly downloaded or translated. Our final data set comprised 10,305 articles. This dataset, containing the text of translated news, country of origin, and the total number of shares, was published and publicly made available on the Zenodo platform [20]. Finally, we processed the data in order to be able to apply the latent Dirichlet allocation (LDA) method. We used R packages (tidytext [21] and textstem [22]) to tokenize text; remove numbers, punctuation, and English stop words; and lemmatize all words.

Statistical Analysis

Topic Modeling

We used LDA [23] to identify the main topics of the 10,305 articles in our data set. We trained multiple LDA models with a different number of topics (ranging from 1 to 40). We then

analyzed perplexity and coherence levels to select the model that best describes our data set. In the next step, 2 researchers individually labeled the topics chosen by LDA to categorize them. The researchers analyzed not only the keywords assigned to each topic but also the content of the 20 articles with the highest amount of contribution to the topic. Initially, they independently described each topic with a freely chosen category. Then, they analyzed the created categories (without knowing the topic they were assigned to) and together created a unified set of categories (eg, education, Europe, and the world). Finally, they classified the topics again with a new set of categories. In this final stage, there were no discrepancies in assessment.

Sentiment Analysis

We calculated the main emotions associated with each article using the syuzhet R package [24]. This package uses the National Research Council Canada (NRC) Word-Emotion Association lexicon. The NRC lexicon is a set of 14,182 English words that are not just concerned with polarity (reporting positive or negative words) but associated with 8 fundamental emotions introduced by Plutchik [25] (ie, anger, anticipation, disgust, fear, joy, sadness, surprise, and trust) [26]. These words were labeled manually by crowdsourcing—each word could be associated with more than one emotion). The sentiment of an article is the sum of emotions related to the words that make it up. The occurrence of each word from one of the categories in the article translates as "1" in the sentiment score for that category. Finally, each article is scored for each sentiment category [27].

Linear Regression

We considered a linear regression model to find the factors determining the number of shares of an article on social media (ie, the dependent variable). We used forward selection regression to create our model. We also used Cook distance method to identify and remove outliers [28] and variance inflation factor to check the existence of collinearity [29]. As independent variables, we used topics generated by the LDA model, the emotions related to the articles, the number of new national measles cases in the month when an article was published, the population of the country, and the percentage of active social media users in each country. The number of new monthly measles cases for each country was collected from the ECDC website [30]. Data on the populations of European countries were obtained from the Eurostat database [31], and the proportion data of active social media users in each country were acquired from the Statista website [32].

Results

Sample Description

After article selection and data processing, we had a final sample of 10,305 measles-related articles, published between January 1, 2017, and December 31, 2019, in European Union countries. The highest number of published articles retrieved was from Italy, but the articles that were the most shared ones were from the United Kingdom. Table 1 shows the number of articles from each country, and the sum and average number of shares. In Table S1 of Multimedia Appendix 1, we present more detailed yearly aggregated data.

Table 1. Description of collected data (N=10,305).

Country	Articles, n (%)	Shares	
		Total	Mean per article (SD)
Austria	200 (1.94)	34,539	173 (425)
Belgium	250 (2.43)	89,442	358 (1095)
Bulgaria	404 (3.92)	23,418	58 (346)
Croatia	53 (0.51)	8395	158 (281)
Republic of Cyprus	9 (0.09)	250	28 (52)
Czech Republic	51 (0.49)	78,043	1530 (3154)
Denmark	114 (1.11)	92,603	812 (2274)
Estonia	13 (0.13)	2546	196 (349)
Finland	119 (1.15)	86,076	723 (2136)
France	1252 (12.15)	633,111	506 (1826)
Germany	1132 (10.98)	914,665	808 (4420)
Greece	697 (6.76)	57,082	82 (792)
Hungary	116 (1.13)	28,851	249 (568)
Ireland	167 (1.62)	32,226	193 (389)
Italy	2025 (19.65)	1,462,172	722 (2983)
Latvia	3 (0.03)	927	309 (520)
Lithuania	1 (0.01)	156	156 (0)
Luxembourg	20 (0.19)	2609	130 (212)
Malta	0 (0)	0	N/A[a]
Netherlands	313 (3.04)	68,705	220 (607)
Poland	216 (2.10)	46,658	216 (1042)
Portugal	964 (9.35)	200,812	208 (1116)
Romania	544 (5.28)	44,363	82 (459)
Slovakia	21 (0.20)	4300	205 (255)
Slovenia	25 (0.24)	2450	98 (232)
Spain	664 (6.44)	954,613	1438 (18,634)
Sweden	253 (2.46)	86,958	344 (1361)
United Kingdom	679 (6.59)	2,012,118	2963 (23,726)

[a]N/A: not applicable.

Topic Modeling

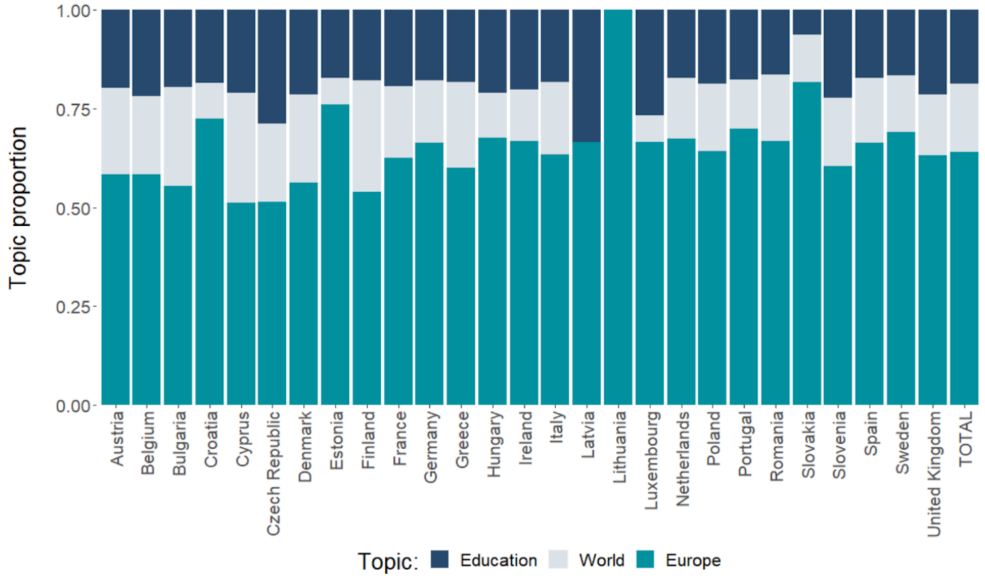
We found that 13 is the best number of topics to describe all collected news articles, accounting for the perplexity and coherence values (Table S2 of Multimedia Appendix 1). After labeling, we discovered that these topics can be aggregated into 3 clusters. The first group contains the topics featured in educational articles, which describe the signs and symptoms of measles infection, debunk antivaccine claims, and explain scientific advancements in the prevention of this disease. The topics in the second group are related to European information, which contain country-specific information on measles outbreaks and health policies. The last group includes topics related to countries outside Europe, including measles cases in the United States, and the Samoa measles outbreak. Table 2 presents the main words connected with specific topics and their classification to general groups.

Table 2. Topics, their classification, and key words.

Topic	Main words	Group classification
Topic 1	immune, immune_system, study, cell, system, researcher, cancer, antibody, virus, memory	Education
Topic 2	child, measles, hospital, Samoa, epidemic, Sweden, people, disease, campaign, patient	World
Topic 3	county, York, measles, city, orthodox, Jewish, disease, USA, Brooklyn, confirm	World
Topic 4	measles, rash, symptom, fever, infection, disease, day, infect, cough, virus	Education
Topic 5	vaccine, parent, autism, child, ani, polio, Wakefield, diphtheria, study, vaccinate_child	Education
Topic 6	MMR, GP, December, England, measles, UK, dose_MMR, jab, HSE, NHS	Europe
Topic 7	vaccination, school, federal, Spahn, measles_vaccination, Germany, day_care, measles, CDU, mandatory	Europe
Topic 8	DGS, health, confirm, directorate, measles, outbreak, age, Portugal, UK, Lisbon	Europe
Topic 9	hospital, measles, Italy, health, Catania, ship, vaccinate, Sicily, hospitalize, region	Europe
Topic 10	country, world, Europe, organization, world_health, health_organization, European, measles, increase, Ukraine	Europe
Topic 11	measles, Roma, CDC, health, dose, Greece, vaccine, population, diseases, Spain	Europe
Topic 12	France, measles, health, agency, Aquitaine, epidemic, health_France, vaccinate, Poitiers, people	Europe
Topic 13	obligation, dolphin, Cicciobello, decree, sport, doll, Burioni, certification, time, market	Europe

Using these 3 clustered meta-topics, we evaluated the popularity of all topics in each country. Figure 1 shows that all of the European countries mainly write about the topic in the European context. Educational topics are more popular than world topics, although the difference between the two varies between countries. In Multimedia Appendix 1, we present sample articles that were highly connected to specific topics.

Figure 1. Distribution of topics across all countries analzyed.



Sentiment Analysis

We analyzed what emotions are connected to measles-related articles in Europe. Figure 2 shows the frequency of appearance of the words associated with a specific emotion in our data set. The most common emotions were fear and trust.

We also determined which words contributed the most to the emotion levels in our data set. For each emotion, we reviewed the 15 most popular words from our data set, as shown in Table 3.

Figure 2. Number of words with a certain sentiment in the data set of articles analyzed.

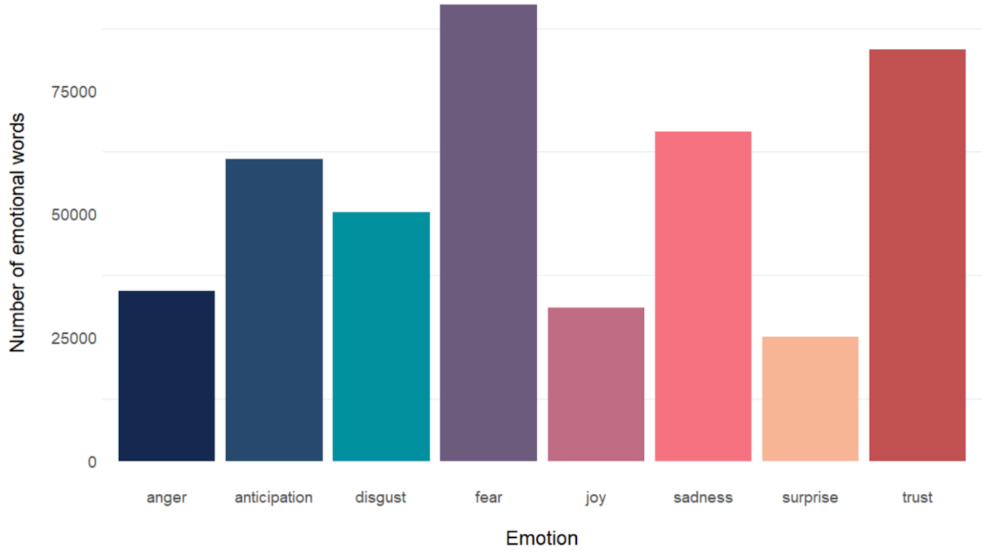


Table 3. Emotions and connected words.

Emotion	Connected words
Fear	disease, infection, death, hospital, epidemic, risk, infectious, contagious, die, medical, fever, prevent, bear, warn, emergency
Trust	accord, hospital, school, doctor, medical, immunization, county, system, organization, authority, recommend, ministry, continue, level, director
Sadness	disease, death, hospital, epidemic, infectious, die, late, sick, emergency, illness, leave, mother, fatal, fall, bad
anticipation	child, death, time, patient, epidemic, risk, public, medical, organization, result, continue, warn, start, prevention, develop
Disgust	disease, death, epidemic, infect, infectious, contagious, rash, cough, sick, bad, ill, nose, elimination, lose, treat
Anger	disease, death, epidemic, bear, fatal, eradicate, bad, ill, force, fear, elimination, victim, lose, treat, fight
Joy	child, organization, ministry, baby, majority, infant, mother, childhood, achieve, safe, grow, treat, create, save, progress
Surprise	death, epidemic, organization, warn, emergency, infant, leave, alarm, expect, catch, lose, treat, sneeze, break, vote

Evidently, fear is connected to words describing the harmfulness of measles. Trust is associated with the words related to health care systems and protection. Sadness is conveyed when describing the adverse effects of the disease; anticipation is conveyed when talking about the actions being taken to reduce the spread of the disease; disgust is associated with the characteristics and signs of measles; anger is about the fight against measles; joy is about children and protecting them from the disease; and surprise is about emergent events. In Multimedia Appendix 1, we present sample articles highly connected to specific emotions.

Linear Regression

We used linear regression to identify the variables related to the number of shares of an article on social media. Table 4 presents the results of the forward selection regression. In the multicollinearity analysis, all variance inflation factor scores were determined to be lower than 5. Therefore, we assumed that there is no collinearity among variables. Detailed results are presented in Multimedia Appendix 1.

We discovered that readers were more likely to share information on topics 1, 4, and 5, which convey educational information. Topics 2, 7, 10, and 13 describe the situation in Samoa, Germany, Ukraine, and Italy, and these topics were also positively associated with the number of total shares. Topic 6, which describes the situation in the United Kingdom, resulted in a reduced number of shares. Topic 4, which describes the signs and symptoms of measles, had the highest impact on the average of shareability.

With regard to emotions, on average, a higher proportion of anger, joy, and sadness expressed in an article was associated with a higher number of article shares, whereas surprise in the article was associated with reduced number of shares. Moreover,

articles published in countries with a higher population and a higher number of active social media users understandably received more shares on social media.

Table 4. Regression results (adjusted R^2=0.04852).

Variable	Beta	Standard error	t value (df)[a]	P value
Constant	–1994	282	–7.08	<.001
Topic 1	1025	218	4.695	<.001
Topic 2	711	127	5.615	<.001
Topic 4	1833	145	12.651	<.001
Topic 5	475	196	2.426	.015
Topic 6	–512	171	–2.994	.003
Topic 7	1024	122	8.42	<.001
Topic 10	616	114	5.388	<.001
Topic 12	184	124	1.487	.14
Topic 13	375	181	2.072	.04
Anger	54	15	3.512	<.001
Joy	53	14	3.66	<.001
Surprise	–50	20	–2.551	.01
Sadness	38	13	2.828	.005
Disgust	–24	15	–1.603	.11
Social media users	22	4	5.112	<.001
Population	0.000018	0.000001	9.393	<.001

[a]df=10,254.

Discussion

Sample Description

The number of articles published from 2017 to 2019 varies across the different countries included in this study. The highest number of articles was published in Italy, which is likely because of the high number of measles cases reported in Italy. During this period, a total of 9252 measles cases were reported in Italy [30]—the highest reported in the European Union. The articles published in the United Kingdom received the greatest number of shares, which might be attributed to the popularity of the English language worldwide. In our data set, less than one relevant article per month was published in Malta, Slovenia, Slovakia, Lithuania, Estonia, Latvia, and Luxembourg. These countries have small populations, and most reported a low number of measles cases during 2017 to 2019. Latvia had a relatively higher number of measles cases, but as was observed (Table 1), despite the low number of measles-related articles published, they were extensively shared on social media. Topic Modeling

European media mostly published news about local events, reporting on almost all significant outbreaks of measles in Europe. However, several of the events received special media attention. The decision of the German government to make the measles vaccine mandatory in response to an increase in measles cases has been frequently discussed in those articles [33]. The measles outbreak in the Aquitaine region in France, caused by insufficient vaccination coverage, is also one of the most described events in the media [34]. Furthermore, measles clusters in the United Kingdom, Portugal, Italy, and Greece are also frequently mentioned in these articles. Some of these articles describe the case of the Cicciobello doll in Italy. The Cicciobello doll is a toy that pretends to be suffering from measles and that children can cure with plasters or cream. Experts have criticized this doll for banalizing such a severe disease [35].

The theme of world news is dominated by 2 events: One is the measles outbreak in the Orthodox Jewish community in New York [36], and the second is the measles outbreak in Samoa [7]. Both these events are interesting because they are concerned with relatively small outbreaks. During the years of analysis, millions of people contracted measles in Africa, Asia, and South America, but this did not attract the attention of European media. As indicated by our data set, media attention was mainly drawn to outbreaks in small, specific communities, and not necessarily to events that had the greatest impact on the lives of millions of people.

Educational themes focus mainly on 3 threads. Some articles describe the symptoms of measles, reflecting the readers' interest in the signs, symptoms, and causes of the disease and their desire to recognize them. The second topic is related to the scientific findings on measles, including studies on the potential oncolytic activity of this virus [37]. The last educational topic dispels the doubts—raised by Wakefield's paper, which has since been

retracted—related to the risk of autism allegedly caused by the MMR vaccine [4]. Moreover, another paper published in 2019, of a nationwide cohort study conducted in Denmark that found that MMR vaccination does not increase the risk for autism, was widely discussed in the media [38].

Sentiment Analysis

In the course of human life, up to 34,000 different emotions can be distinguished [39]. Psychologist Robert Plutchik proposed the theory of 8 basic emotions, which have developed evolutionarily and are innate in humans and help them survive [25,40]. As a result of combining these basic emotions, more complex emotions responsible for specific experiences arise (eg, joy + trust = love; trust + fear = submission). Basic emotions are triggered by specific events, eliciting an appropriate response that has an evolutionary function. Table 5 presents the characteristics of these basic emotions as proposed by Plutchik [40].

Table 5. Characteristics of basic emotions.

Emotion	Stimulus event	Behavioral reaction	Function	Opposite emotion
Joy	Gain of a valued object	Retain or repeat	Gain resources	Sadness
Trust	Member of the group	Groom	Mutual support	Disgust
Fear	Threat	Escape	Safety	Anger
Surprise	Unexpected event	Stop	Gain time to orient	Anticipation
Sadness	Loss of a valued object	Cry	Reattach to the lost object	Joy
Disgust	Unpalatable object	Vomit	Eject poison	Trust
Anger	Obstacle	Attack	Destroy obstacle	Fear
Anticipation	New territory	Map	Knowledge of territory	Surprise

Emotions are an important part of media articles, as emotional stories attract readers' attention [41]. The most common emotion identified from all collected articles was fear. The creation of fear-based articles is consistent with the results of studies that show that fear-related news reports automatically attract public attention [42]. In the case of the articles analyzed in this study, the emotion fear was mainly concerned with the fear of the disease and its consequences. This emotion is so strong that sometimes the fear of disease is worse for a patient than the disease itself [43].

The analyzed articles were also highly connected with trust. There is a natural link between fear and trust because it is in response to concerns about a dangerous disease that we place our trust in the health care system and the vaccines that protect us against the pathogen. Research conducted during the Ebola epidemic showed that trust in the health care system increased during the outbreak [44].

In the field of marketing, the relationship between the basic emotions in the text and its potential to go viral has often been examined. An analysis of 7000 articles published in The New York Times revealed that positive content tends to go viral more than negative content. More specifically, this study has demonstrated that sad content is less likely to go viral, whereas articles expressing anger or anxiety result in higher number of shares on social media [45]. Teixeira [46] analyzed thousands of reactions to several advertisements and found that maintaining viewers' engagement levels is associated with the emotions of joy and surprise. Libert and Tynski [47] also found that emotional activation is the key to viral success. They used Plutchik's set of emotions [25] and found that negative emotions are not commonly present in highly viral content. Surprise and anticipation are also extremely common in highly viral content.

Linear Regression

We identified a few features of news articles that are associated with an increased number of shares on social media. All educational topics are positively connected with the number of shares. This shows that social media users generally prefer to share general educational news over informational ones. This finding is consistent with the results of previous research, wherein it was proved that Facebook users are more likely to share "soft" news related to children, health, and education than "hard" news related to politics or urgent occurrences [48]. Sharing educational and scientific articles can also be associated with the willingness to increase one's credibility, self-confidence, and self-esteem from other social media users [49].

The results also show that information on the events in Sweden, Germany, Italy, and Ukraine was shared frequently, whereas the publication of information on the situation in the United Kingdom was negatively associated with the number of social media shares. The interest in measles in Ukraine may have been generated as a result of the country having the highest number of measles cases in Europe. In 2017-2019, the number of measles cases in Ukraine was around 100,000 [50]. This situation was similar to the interest in measles cases in Italy, where the highest number of cases among all countries in the European Union was reported during the study period [30]. Furthermore, research conducted by Facebook showed that country-based or cultural differences have an impact on Facebook activity. In the United Kingdom, social media users are younger but less active than those in Germany or Sweden [51].

The findings of previous research analyzing what type of web-based content become viral are generally in line with our results. They indicate that articles containing positive emotions or anger are more likely to be shared [45].

Conclusions

Articles on measles shared on social media in Europe primarily report on European events, and only a small proportion of articles report on educational news or international measles-related events. The international events mainly describe outbreaks that have occurred in a small number of infected people but are interesting from an epidemiological point of view. The distribution of topics covered by the media is similar across all European Union countries.

In this study, the two main emotions expressed in the analyzed measles-related articles were fear and trust. These emotions appeared in the articles most frequently. However, these emotions were not associated with frequent sharing of articles on social media. We found that an article has a high probability to drive public discourse if it contains educational or scientific information, as well as specific emotions (ie, anger, joy, or sadness). Making media content based on these principles can facilitate the creation of effective messages against measles vaccine hesitancy. Articles that follow these principles offer the best chance of disseminating information to a broad audience on social media and influencing the mindset of the public regarding vaccines.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Supplementary tables providing details of the analyses conducted.
[DOC File , 231 KB-Multimedia Appendix 1]

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Abbreviations

ECDC: The European Centre for Disease Prevention and Control
LDA: latent Dirichlet allocation
MMR: measles, mumps, and rubella

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What Arguments against COVID-19 Vaccines Run on Facebook in Poland: Content Analysis of Comments

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Abstract: Social media allow anti-vaxxers to quickly spread misinformation and false statements. This situation may lead to an increase in vaccine hesitancy. We wanted to characterize what arguments against COVID-19 vaccines run on Facebook in Poland. We analyzed Facebook comments related to the five events of the introduction of COVID-19 vaccines—announcements of the efficacy of the Pfizer-BioNTech (09.11.2020), Moderna (16.11.2020), and AstraZeneca (23.11.2020) vaccines, registration of the Pfizer-BioNTech vaccine by the European Medicines Agency (21.12.2020), and the first vaccination in Poland (27.12.2020). We collected the comments from fanpages of the biggest Polish media and then established their main anti-vaccine themes. We found that the negative arguments about COVID-19 vaccines can be divided into 12 categories. Seven of them are universal and also apply to other vaccines but five are new and COVID-19' specific. The frequency of arguments from a given category varied over time. We also noticed that, while the comments were mostly negative, the reactions were positive. Created codebook of anti-vaccine COVID-19 arguments can be used to monitor the attitude of society towards COVID-19 vaccines. Real-time monitoring of social media is important because the popularity of certain arguments on Facebook changes rapidly over time.

Keywords: Facebook; vaccine hesitancy; vaccine; COVID-19; infodemiology

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1. Introduction

1.1. Background

Social media provide great opportunities for sharing convictions and opinions. Unfortunately, there is also a place for conspiracy theories. Almost half of the health content published on social media contains misinformation [1]. The subject of vaccinations and infectious diseases is, next to oncological topics, the most frequently misrepresented in social media [2]. For these reasons, social media are currently regarded as the main communication tool for people with anti-vaccine attitudes [3,4].

An example of an uncontrolled spread of misinformation on vaccination on social media is the measles outbreak in Samoa. In July 2018, two Samoan children died after MMR vaccination because nurses inadvertently used curare instead of water to dilute the MMR vaccine. This resulted in an increased activity of local anti-vaxxers on Facebook, who took action to discourage vaccination [5]. As a result, measles vaccination coverage in Samoa decreased to 31% [6]. Consequently, measles outbreak occurred on the islands in September 2019, causing over 5000 cases and 83 deaths in a country with the population of 200,000 [7]. Finally, the authorities decided to organize a vaccination campaign and arrest some anti-vaccination campaigners spreading misinformation on Facebook [8]. When 95% of eligible people in Samoa got vaccinated, the outbreak was eliminated [9]. Another case happened during the COVID-19 pandemic when European trust in AstraZeneca's vaccine plummeted after spreading information on rare episodes of blood clotting after the vaccination [10]. This decline in confidence has occurred in spite of the European Medicines Agency's

statement that the overall benefit-risk of this vaccine is positive and that blood clots are a very rare side effect [11].

These cases show that negative online information on vaccination is one of the leading causes of vaccine hesitancy [12]. The Internet has a huge impact on society's decisions as 70% of Internet users make decisions about vaccination on the basis of information found there [13], which discourages almost half of the parents [14]. Even a few minutes of contact with anti-vaccine information on the Internet negatively affects the perception of vaccine-related risks [15] and reduces parents' willingness to vaccinate their children [3]. Recently, Facebook and Instagram have taken steps to stop the spread of misinformation, making it difficult to be found. Unfortunately, this type of content has still not been completely removed from these platforms [16,17].

When we analyze online comments on vaccinations, attention should also be paid to the features of social media. Facebook's user-generated content is more difficult to obtain and analyze than Twitter's content, because this platform does not provide an application programming interface (API) allowing to automatically search and retrieve data. Despite these obstacles, Facebook can provide much more accurate data on public opinion. In comparison to Twitter or Instagram, Facebook has not only much more active users, but the demography of its users is similar to whole society's demography. Twitter and Instagram have an overrepresentation of young, well-educated, and living-in-cities users [18].

Anti-vaccine social media content is especially dangerous because it is often professionally created and catches the audience's eye. Authors of such content use celebrities and personal stories talking about negative effects of vaccines [19], but their content is rarely created by health care professionals [20,21]. They underline side effects and vaccination risks causing fear in their audience [22,23]. This tactic is based on behavioral research showing that fear-related information attracts audience attention [24]. Additionally, almost a quarter of anti-vaccine social media content contains conspiracy theories [25]. The effect of all these characteristics is the high popularity of anti-vaccine content, often viewed and shared by social media users [22,26,27].

During the COVID-19 pandemic, vaccine hesitancy may delay the combat of SARS-CoV-2 virus despite vaccines' quick development [28]. The studies conducted so far indicate that not all social groups want to be vaccinated equally willingly [29]. Surveys show that about a quarter of Europeans do not want to take COVID-19 vaccine [30]. Therefore, in order to take full advantage of the great scientific success, it is necessary to study public opinion, because trust in science and the general attitude towards vaccines' efficacy have an impact on the willingness to vaccinate against COVID-19 [31].

1.2. Aim

We wanted to find out and categorize negative public opinions on COVID-19 vaccines. To achieve this goal, we tried to categorize the content created by Facebook users. We focused on comments published in the response to the news published on Polish media fanpages, describing COVID-19 vaccines' development.

In our research, we seek to answer three research questions:

RQ1: What arguments do Facebook users employ against COVID-19 vaccines? Have they created new anti-vaccine arguments specifically connected to this pandemic and not existing before in the context of other vaccines?

RQ2: How does the popularity of arguments against COVID-19 change over time?

RQ3: What reactions on COVID-19 vaccines do Facebook news receive? How have these reactions changed over time?

2. Materials and Methods

2.1. Data Collection

To collect data, we created a list of the most popular Polish media by the number of users (newspapers, TV stations, radio stations, news websites). For each medium, we found an official Facebook fanpage. Finally, we had a total of 14 fanpages in our dataset. We present an overview of the analyzed media in Table 1.

Table 1. Media included in the study.

Fanpage	Type of Media	Number of Facebook Fans
fakt24pl	newspaper	1,138,628
wyborcza	newspaper	757,197
dziennikrzeczpospolita	newspaper	135,033
wwwsepl	newspaper	122,522
radiozet	radio station	961,349
rmf24	radio station	424,580
Onet	news website	1,141,477
gazetapl	news website	796,400
wiadomosciwppl	news website	688,382
portalo2pl	news website	450,600
interia	news website	107,192
tvn24pl	TV station	1,472,732
tvp.info	TV station	401,223
polsatnewspl	TV station	239,761

In the next step, from 1 November 2020, we started to look for highly-commented events in Poland, related to COVID-19 vaccines. The authors decided by consensus which events should be included in the study. We planned to end our observation when the first person would be vaccinated in Poland.

As a result, we added five highly-commented events in Poland to our analysis, which are described in Table 2. The first news was three week-by-week events related to the end of the vaccine research. Pfizer-BioNTech was the first to announce the completion of the research, followed by Moderna and AstraZeneca. The next event was the registration of the Pfizer-BioNTech vaccine by the European Medicines Agency (EMA). Finally, we analyzed the comments connected to the news about the first vaccination in Poland.

Table 2. Events included in the study.

Event	Date	Number of Comments	Number of Reactions	Number of Shares	Number of Media that Reported
Pfizer-BioNTech announces effectiveness of the vaccine	9 November 2020	7181	9608	702	14
Moderna announces effectiveness of the vaccine	16 November 2020	2117	3522	139	13
AstraZeneca announces effectiveness of the vaccine	23 November 2020	2160	2151	135	8
registration of the Pfizer-BioNTech vaccine by EMA	21 December 2020	2017	3059	130	13
first vaccination in Poland	27 December 2020	13,254	15,626	682	14

We conducted the same analysis for each event. One week after the event, when the number of new comments and reactions on social media typically falls sharply [32], we collected data. We searched for a post describing the analyzed event on every fanpage from our list. Secondly, we downloaded all comments (using the tool exportcomments.com, accessed on 1 May 2021) and all the reactions connected to this post. In summary, we collected 22,791 comments for further analysis.

2.2. Themes of Comments

We wanted to create a codebook of categories of Facebook opinions against COVID-19 vaccines. Firstly, from our comments dataset, we randomly chose 1000. Then, we decided to use the list of categories of vaccine-related social media comments proposed by Broniatowski et al. [33] as a base set of topics to which we tried to assign each of the comments. Two researchers (DW and MP) independently labeled every comment with one category. If there was no proper category in our primary set, we created a new category. Finally, we established by consensus the codebook with 12 main themes of anti-COVID-19 vaccines comments.

2.3. Data Analysis

From each post, we chose 15% most-reacted comments for further analysis. In the next step, five researchers wanted to assign those 3414 comments to categories from our codebook.

Firstly, we assessed our interrater reliability. We got 50 random comments and each of evaluators (DW, MP, JG, KK, MJ) independently assorted each comment into one category. Then, we calculated the value of Krippendorff's Alpha [34] to estimate interrater reliability among coders, finding that our interrater agreement was high ($\alpha = 76\%$).

As there was a large consensus on our assessments, we decided to evaluate the comments individually. We divided our dataset of 3414 comments into five parts, with one researcher coding 682 comments, and the other four coding 683 comments each.

3. Results

3.1. Data Overview

In Table 2, we present all events included in our analysis. For each event, we show the date of news publication, the number of comments, reactions, and shares in all included media. Besides that, we display a column with the number of media which posted the information, because not all media reported every event. The first vaccination in Poland was the most commented event and also got the most reactions. The second most popular event was the first information at the end of vaccine research.

3.2. Research Question 1

We found that comments on COVID-19 vaccines can be divided into 13 categories, 12 negative and 1 positive, presented in Table 3. Seven categories are similar to general themes of anti-vaccine social media posts, previously described in the literature [33]. Five themes are new and specific to COVID-19 anti-vaccine sentiment. They argue that these vaccines have been developed too quickly without a proper test. They also suggest that vaccine does not exist despite the information from pharmaceutical companies and governments. Some users remind about the development of the swine flu vaccine. This vaccine was also developed quickly, but, over time, it caused more side effects than expected. On the other hand, conspiracy theories suggest that vaccines against COVID-19 existed before the official announcement, even before the pandemic. The last specific argument implies that people should avoid vaccination because no one takes responsibility for the potential side effects of the vaccine. Only 15% of the comments were positive, while 85% were negative.

Table 3. Themes of comments and examples from our dataset, new COVID-19 vaccine specific themes are in bold.

Theme	Example Comment from Our Dataset
positive attitude	I will get vaccinated as soon as there is an opportunity. I can record it and send to all those with anti-vaccine views.
lack of trust in the government	First, let the government test it on themselves and after some time we'll see if it's so cool.
the vaccine will be dangerous to health	The television fools you. Vaccines are death.
COVID-19 disease does not exist or is not dangerous to health	Why the vaccine if there is no COVID?
I do not want to be vaccinated because I have freedom of choice	I'm not gonna be a guinea pig.
conspiracy theories, hidden vaccine effects (e.g., chips)	It is about implanting people with chips or some other shit.
the vaccine was created only for the profit of pharmaceutical companies	They created the virus, gave it time to enter the human psyche and arouse fear, they created the demand, and now they provide the supply of the vaccine everyone wants and will pay trillions.
natural methods of protection against the disease are better than vaccines	No vaccine can give you a 100% guarantee. I prefer to naturally strengthen my immunity and not to get sick.
the vaccine does not exist or will not work	They will be vaccinated with saline in front of all people. They will think these are real vaccines.
the vaccine has existed before the COVID-19 epidemic	They had a vaccine a long time ago. Now there is too much resistance. They still have to train people to give up easier.
the vaccine is not properly tested, it has been developed too quickly	Normal vaccines have been produced and tested for a minimum of 8 years. And here ... less than a year and ready. I wonder what these people will go through in a few years.
mentioning the past development of the swine flu vaccine	There was already a swine flu vaccine invented in a few months. Poland, fortunately, did not have money for it, but Sweden pays compensation to people who got vaccinated for side effects, e.g., narcolepsy.
no one is responsible for the potential side effects of the vaccine	If this vaccine is so great, why are pharmaceutical companies released from liability for side effects?

3.3. Research Question 2

In this part of our research, we checked the popularity of topics found in the previous step. The most popular anti-vaccine arguments in our dataset are: the lack of trust in the government, the danger of vaccines, and the lack of faith in the existence of an effective vaccine. We can notice that a share of pro-vaccine comments has been growing over time. It has increased from 7% to 22% during the event of first vaccination. Figure 1 shows the distribution of themes over time.

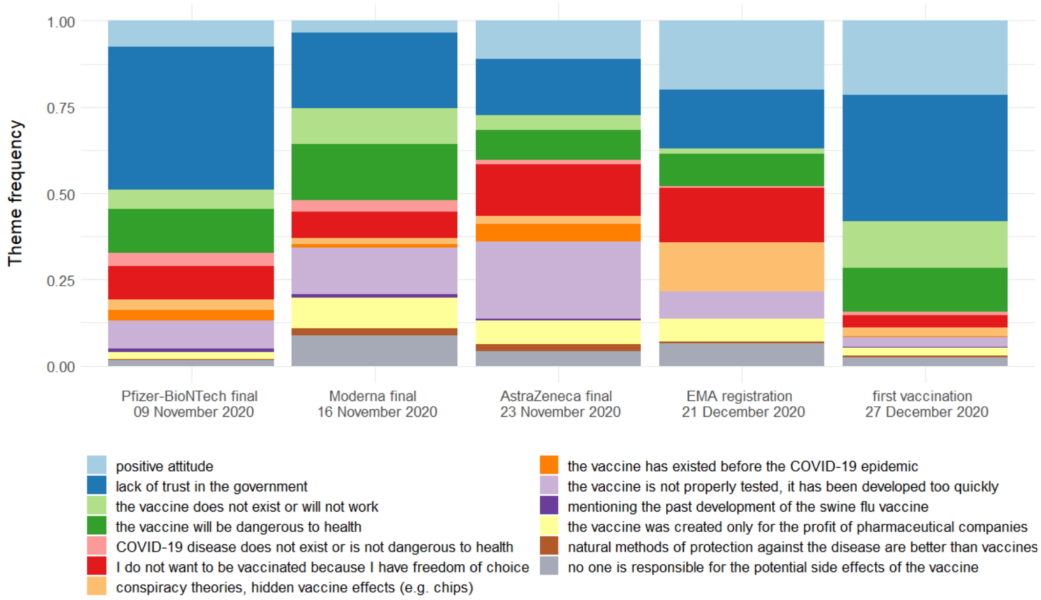

Figure 1. Distribution of themes.

In the first three events informing about the completion of vaccine studies, there are visible doubts about the vaccine being developed too quickly and not adequately tested. With the completion of studies of the second and the third new vaccine (Moderna, AstraZeneca), these doubts grew. Regarding the completion of research on the Moderna and AstraZeneca vaccines, there are also a lot of comments suggesting that the vaccines were created only for money. After European Medicines Agency (EMA) registration of Pfizer-BioNTech vaccine, a fear of improper testing has faded away. Then, the focus shifts to convictions that the vaccine is not working.

The first and last events have a similar topics' distribution, especially regarding a high aversion to the government. On the other hand, after the EMA approved the Pfizer-BioNTech vaccine, we have a lot of conspiracy theories and little criticism of the government.

3.4. Research Question 3

Figure 2 shows Facebook users' reactions to the news. We introduced reactions such as 'like', 'love', 'care', and 'wow' in the positive group and reactions such as 'angry' and 'sad' to the negative group. Reaction 'haha' was classified as 'other'. We referred to the findings by Giuntini et al. [35] for this classification, describing Facebook reactions' sentiment. The positive-to-negative-reactions ratio has increased over time. It is interesting that positive reactions prevailed over negative ones, while the comments remained strongly negative.

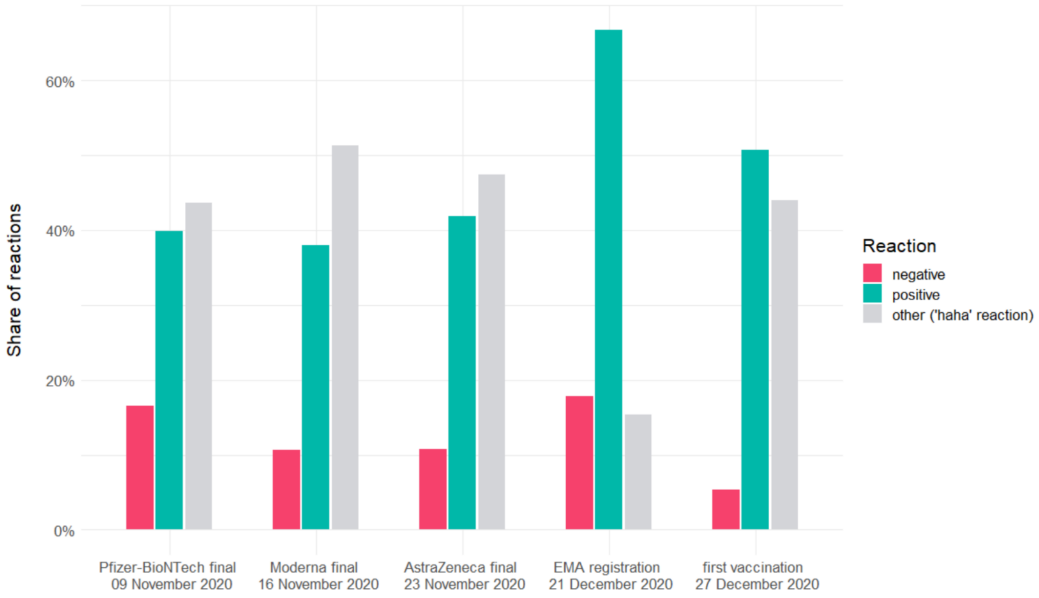

Figure 2. Reactions connected to the news.

4. Discussion

4.1. Overview

We found that negative COVID-19 vaccine comments can be divided into 12 categories. Seven of these arguments are universal and also apply to other vaccines, but five types are new and COVID-19-specific. New topics say that the COVID-19 vaccines do not exist or work, are not properly tested, have existed before the epidemic, can be dangerous as previous flu vaccine, or no one is responsible for potential side effects.

Our codebook of anti-vaccine COVID-19 arguments can be used by public health specialists and researchers to monitor society's attitude to COVID-19 vaccines. Real-time social media monitoring is important because we have found that popularity of certain arguments on Facebook changes rapidly over time.

4.2. Main Topics of Anti-Vaccine Comments

The most common arguments against COVID-19 vaccines are based on the lack of trust in the government, which is responsible for organizing the vaccination programs. This is consistent with previous studies, showing that low trust in the government is related to vaccine hesitancy [36]. It is important to pay attention to the role of governments in the communication of vaccination [37]. Satisfaction with the government can influence vaccination beliefs and willingness to get vaccinated [38]. This thread requires further comparative research in other countries, as OECD data shows that Poland's citizens generally have one of the lowest levels of trust in the government in Europe [39].

Another anti-vaccine comments' topic suggests that COVID-19 vaccines are dangerous to health. It is one of the most common arguments used by anti-vaxxers to create fear [40]. This topic is especially dangerous when we understand that emotional stories and fear-related information highly attract the audience's attention [24,41]. Other general arguments mention that infectious diseases (in this case COVID-19) are not dangerous, or that natural methods of obtaining immunity are more effective.

Facebook users often express the opinion that they do not want to be vaccinated because of a free choice that no one should limit. It can be connected to the recent research showing that people have a reduced risk perception of being ill with COVID-19 [42]. Some of the comments deal with conspiracy theories. Most often, they contain general arguments not strictly related to the COVID-19 vaccine, such as microchips in vaccines. Generally, anti-vaccine social media content often presents unverified information [22]. In the case of COVID-19, anti-vaccine users claim that vaccines were developed only for the pharmaceutical corporations' profit, and not for society's health. This argument is interesting in the context of AstraZeneca's announcement that it will not profit from the COVID-vaccine [43].

Facebook users also employed specific arguments against COVID-19 vaccines that have not been common in the anti-vaccine discourse so far. Many accuse the vaccine of being developed too quickly and without a properly test. These doubts are most likely caused by the speed of clinical trials and registration [44]. It is important for public health authorities to publicly emphasize that vaccines registered in the European Union and the USA have undergone the entire registration process [45,46]. Anti-vaccine commenters often mention the fast development of the swine flu vaccine. They underline that this vaccine was created very quickly and presented as safe, like the COVID-19 vaccine, but, in Sweden, increasing cases of narcolepsy were reported after vaccination [47].

Another theme suggests that no one is responsible for vaccines' side effects. This is a false because European governments set up a compensation fund to offer payments to people suffering with severe side effects after vaccination [48,49]. Some people say that COVID-19 vaccines existed before the COVID-19 pandemic. This claim could be based on the popular conspiracy theory suggesting that the virus was purposefully created and spread [50]. The last specific anti-vaccine argument says that the vaccine probably does not exist, and all information about efficiency and successful registration is fake. This can be connected with a conspiracy theory that COVID-19 was created as a biological weapon [51].

4.3. Changes in Content Over Time

Five researchers categorized comments. To assess their interrater reliability we used Krippendorff's Alpha method which allows the assessment of agreement between more than two researchers. The calculated alpha value was 76%. According to the article published by Krippendorff, conclusions are acceptable when $\alpha >= 0.667$ [52]. In our case, some discrepancies in the assessment were caused by the ambiguity of the comments. In some of the comments, it was not clear whether the user was making a negative argument or if was in favor of vaccinations, but the comment was ironic. In such situations, there could be a discrepancy in the assessment between the evaluators. Previous studies have shown that without paralinguistic cues like gestures or intonation it can be difficult to detect sarcasm in online messages [53,54].

Over time, the number of positive comments about vaccination against COVID-19 has increased. The reasons for this situation are multifactorial. On the one hand, trust grows with time [55]. History shows that new technologies were often not trusted at the time of their creation, before society understood the benefits and risks of a given technology [56]. Additionally, media systematically presented the vaccine as a great success, building trust and willingness to vaccinate. In December, Polish public health authorities conducted education campaigns to convince society that COVID-19 vaccines are effective, safe, and properly tested.

We also found that shares of negative themes vary over time. During the news of the completion of the vaccine research, there were many doubts in the comments about fast vaccine development and concerns about proper testing. This is reinforced by the fact that information about the completion of three studies appeared within 2 weeks after just 9 months of development [28,57,58]. Considering the complexity of the process, obtaining results so quickly could cause public distrust. These concerns were widely commented on by public health experts, who explained that the clinical trial process had passed all

necessary formalities [59]. An example of the early undertaken action in response to popular anti-vaccine arguments is the activity of the Polish National Institute of Public Health. In December 2020, after the announcements of the efficacy of the vaccines, many comments on Facebook were saying that the vaccines are not properly tested. In the response to these doubts, the Institute started an action on social media explaining what the clinical trials of vaccines involve. This could potentially lead to the reduction of the popularity of the argument that the vaccines were developed too quickly. Our study shows that such a decline was visible at the end of December. The theme of the comments began to change in the direction that the vaccines do not work. Besides, in our comments' dataset, many users misinterpreted the vaccine efficacy data, suggesting for example that 90% efficacy means that 10% of patients have severe side effects. Data misinterpretation is a common tactic by anti-vaccine movement to affect vaccine decisions [60].

The positive-to-negative-reactions ratio has increased over time. One of the reasons may be a better understanding of the situation and vaccines' characteristics. Over time, recipients have had the opportunity to read a variety of information and dispel some of their doubts. At that time, the Polish public health authorities conducted information campaigns that could have caused this effect [61]. There is also a discrepancy between the sentiment of the comments and the sentiment of the reactions. A vast majority of comments are negative, while the reactions are mostly positive. This is in line with the research by Yang et al. [62], who found that Facebook users publish two times more negative than positive comments on fanpages.

Currently Facebook users can use 7 reactions ('like', 'love', 'care', 'wow', 'angry', 'sad', 'haha') which allow them to react to posts with emoticons. Such a large number of available reactions is a relatively new phenomenon, it was introduced on Facebook in 2016. So far, there have not been many papers exploring how users use these animated reactions. One of the first comprehensive attempts to identify emotional expressions of Facebook reactions was made by Giuntini et al. [35]. According to their results, we classified 'like', 'love', 'wow', and 'care' as reactions used by COVID-19 vaccines supporters. We categorized the 'sad' and 'angry' reactions as used by people reluctant to COVID-19 vaccines. The unambiguous assignment of the 'haha' reaction was problematic. This reaction should be used in response to funny content. In practice, as demonstrated by Giuntini et al. [35], it is not related to any specific emotion and is used in a variety of contexts. Facebook users use this reaction as a positive, negative, or neutral with similar frequencies. Since it is impossible to determine the exact sentiment of the 'haha' reaction, we assigned it into the 'other' category.

5. Conclusions

The development of COVID-19 vaccines has prompted new arguments among anti-vaxxers. They accuse the vaccines of not being properly tested and safe. However, their main doubt is a classic argument that they do not trust the government which is responsible for vaccination campaigns.

The comments regarding vaccination have an overwhelmingly negative sentiment, but the reactions are positive. This suggests that pro- and anti-vaccine groups have different patterns of dealing with social media content. This is an important finding because many researchers analyze only the sentiment of Facebook reactions without focusing on the comments.

Our codebook of anti-vaccine topics, presented in Table 3, can help public health professionals to better understand social media content. Early recognition of social doubts allows for targeted information campaigns. Additionally, our codebook can be a contribution to future analysis by researchers and public health specialists who monitor society's attitude towards COVID-19 vaccines.

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Attitudes toward COVID-19 Vaccination on Social Media: A Cross-Platform Analysis

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Abstract: During the COVID-19 pandemic, social media content analysis allowed for tracking attitudes toward newly introduced vaccines. However, current evidence is limited to single social media platforms. Our objective was to compare arguments used by anti-vaxxers in the context of COVID-19 vaccines across Facebook, Twitter, Instagram, and TikTok. We obtained the data set of 53,671 comments regarding COVID-19 vaccination published between August 2021 and February 2022. After that, we established categories of anti-vaccine content, manually classified comments, and compared the frequency of occurrence of the categories between social media platforms. We found that anti-vaxxers on social media use 14 categories of arguments against COVID-19 vaccines. The frequency of these categories varies across different social media platforms. The anti-vaxxers' activity on Facebook and Twitter is similar, focusing mainly on distrust of government and allegations regarding vaccination safety and effectiveness. Anti-vaxxers on TikTok mainly focus on personal freedom, while Instagram users encouraging vaccination often face criticism suggesting that vaccination is a private matter that should not be shared. Due to the differences in vaccine sentiment among users of different social media platforms, future research and educational campaigns should consider these distinctions, focusing more on the platforms popular among adolescents (i.e., Instagram and TikTok).

Keywords: Twitter; Facebook; Instagram; TikTok; social media; COVID-19 vaccine; vaccine hesitancy; public health

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1. Introduction

1.1. Background

During the COVID-19 pandemic, social media became a space of intense debate about vaccines, encountering a wave of comments discouraging COVID-19 vaccination, even before their official introduction [1,2]. Negative sentiment on social media persisted after the start of the vaccination campaign [3,4], although the vaccination of millions of people has demonstrated the safety and efficacy of COVID-19 vaccines [5].

Anti-vaccine social media activity is considered one of the leading causes of vaccine hesitancy [6,7]. About 40% of frequently shared health information on social media contains text classified as fake news, and the most fallacious content concerns vaccines [8]. The experiment conducted by Betsch et al. revealed that even 5–10 min of access to anti-vaccine websites decrease the intention to vaccinate and increase the perception of risk [9]. During the COVID-19 pandemic, social media was one of the main information sources on newly introduced vaccines [10]. However, the influence of social media on attitudes towards vaccination against COVID-19 is unclear. Social media's negative and positive effects on the perception of safety and the willingness to vaccinate against COVID-19 have

been reported [11–14]. The analysis of vaccine-related social media opinions is especially important considering the high dynamic of COVID-19 vaccine hesitancy in society [15,16].

Previous research has shown that arguments against COVID-19 vaccines running on social media have mainly expressed distrust of governments and pharmaceutical corporations, fear of side effects, allegations of insufficient testing of vaccines, and accusations of ineffectiveness [2,3,17]. Prior to the pandemic, subjects regarding insufficient vaccine testing and ineffectiveness, commonly discussed in the context of COVID-19 vaccines, were virtually absent in the anti-vaccine discourse [18]. Conversely, the historically popular theme linking vaccination to the development of autism in children has disappeared during the pandemic [19]. Anti-vaccine arguments on social media vary over time, making it necessary to monitor them regularly in different phases of the COVID-19 pandemic [2,3].

Thus far, analyses of social media content against COVID-19 vaccines have focused on single platforms. The most frequently analyzed platform is Twitter, which allows researchers to retrieve thousands of tweets automatically [1,3,4,20–22]. A few content analyses were conducted on Facebook and Instagram [2,17,23,24], and one paper examined content on TikTok [25]. The lack of multi-platform analyses leaves knowledge regarding attitudes toward COVID-19 vaccination incomplete and selective, since there are significant sociodemographic differences among the users of different social media platforms. The major differences include gender, age, and income [26]. Thus, none of the social media platforms provide a complete cross-section of society; however, it has not been investigated whether these sociodemographic differences influence attitudes toward COVID-19 vaccination across social media platform users. Depending on the social platform, the impact of content on the user's well-being is different. Therefore, the platforms must be differentiated in research to fully understand users' attitudes and behaviors [27].

The lack of cross-platform comparative analyses is mainly due to the difficulty of simultaneously studying different types of content. For instance, Twitter users write short text messages, whereas Facebook users mostly post long text messages often combined with images. Instagram focuses on presenting pictures, while TikTok offers short videos [27]. This paper studies differences in attitudes toward vaccination by using a single hashtag that gained popularity on Facebook, Twitter, TikTok, and Instagram and provided a unique opportunity to conduct a comparative analysis among different social media platforms.

1.2. Aim of the Study

The purpose of this study is to analyze the arguments used by anti-vaxxers on social media in the context of COVID-19 vaccination, with a focus on differences in sentiment and themes across Facebook, Twitter, Instagram, and TikTok. We seek to answer three research questions:

RQ1: What arguments do social media users employ against COVID-19 vaccines?

RQ2: Which anti-vaccine arguments regarding COVID-19 vaccination are the most popular on social media?

RQ3: Do users of different social media platforms (i.e., Facebook, Twitter, TikTok, and Instagram) have different concerns about COVID-19 vaccination?

2. Materials and Methods

2.1. Data Collection

We used the Polish hashtag "#szczepimysie" (English translation: "#wevaccinateourselves") to retrieve posts on COVID-19 vaccines. This hashtag was promoted by the Polish government during the COVID-19 pandemic and was intended to promote vaccination against COVID-19. Eventually, this hashtag became a universal label for all social media content regarding COVID-19 vaccination in Poland, both positive and negative. The widespread dissemination of this hashtag enabled cross-platform analysis and allowed for a unified comparison between social media platforms.

We built the data set based on comments on the posts that were published under the hashtag "#szczepimysie" from 1 August 2021 to the 1 February 2022. We selected the 200

most popular posts; 50 posts from each of the four platforms (i.e., Facebook, Twitter, TikTok, and Instagram). For this purpose, we used a built-in feature of each platform, which allows for displaying posts from a given hashtag sorted by popularity. Then, we downloaded all comments published in response to the 200 most popular posts. We also obtained the number of reactions to each comment. Facebook reactions include all extensions of the "Like" button ("Like", "Love", "Haha", "Wow", "Sad", or "Angry"). Meanwhile, likes constitute the only available reaction on Twitter, TikTok, and Instagram. Using the exportcomments.com tool (accessed on 9 March 2022) [28], we retrieved 24,869 comments from Facebook, 8721 comments from Twitter, 2997 comments from Instagram, and 17,084 comments from TikTok.

2.2. Data Categorization

We identified the main topic categories of the comments in our data set. First, we created an initial codebook of anti-vaccine themes on social media based on previous research conducted by Wawrzuta et al., Huangfu et al., and Broniatowski et al. [2,3,18]. In the second step, we randomly selected 100 comments from the collection, and two researchers (D.W. and J.K.) categorized the comments using this initial codebook. In the cases where we could not find a proper category for a comment, we created a new category by consensus. Finally, we removed all unused categories from the initial codebook and created a final codebook of anti-vaccine themes.

Our final data set for categorization and further analysis included 1000 comments. It was constructed by selecting 250 comments with the most reactions from each of the four platforms. Before annotating the comments in the final data set, we checked the interrater reliability. First, two researchers (D.W. and J.K.) independently classified 100 randomly selected comments (25 from each platform) into categories. Then, we calculated Krippendorff's Alpha value [29] to estimate our interrater agreement. We found that the agreement was high ($\alpha = 0.919$). Finally, we discussed the divergence in the assessments, and we assigned the differently rated comments to categories through consensus. As the concordance of the assessments was high, we conducted further classification individually. We divided the remaining 900 comments equally between the two researchers (D.W. and J.K.), who independently assigned comments to the categories.

2.3. Keyword Extraction

We used a measure of relevance of a term to a category to extract the most useful keywords for differentiating between categories [30]. The calculation was based on the word counts within categories and in the corpus. To create these counts, we first performed the following pre-processing steps: (i) delete URLs, hashtags, and usernames in the Twitter mentions and emojis; (ii) translate the comments into English using DeepL API [31]; (iii) remove digits, punctuation, and stopwords; (iv) lemmatize words (reduce words to their dictionary form) using WordNet® lemmatizer [32] with the Stanford Part of Speech tagger [33].

After these pre-processing steps, we calculated the relevance of each term to each category. The intuition behind the relevance score is as follows. Terms that appear more frequently in a category are more relevant for this category. Terms that are frequent overall are less relevant, because they do not help to form distinct categories. Let V denote the number of unique terms in the corpus and K indicate the number of categories. Let $\phi_{k,w}$ denote the number of occurrences of term $w \in \{1, \ldots, V\}$ in category $k \in \{1, \ldots, K\}$, divided by the total number of terms in the category. Let p_w denote the number of occurrences of term w in the corpus divided by the total number of terms. The relevance is defined as:

$$r(w, k|\lambda) = \lambda \, log(\phi_{k,w}) + (1 - \lambda) log\left(\frac{\phi_{k,w}}{p_w}\right)$$

The first component in the above sum represents the empirical probability of a term in a category. The second component represents a term lift, i.e., ratio of a term's probability

within a category to its marginal probability within a corpus [34]. This generally down-weights globally frequent terms. A parameter (λ) determines the weight given to each of the two components (we set $\lambda = 0.5$). Finally, we ranked the keywords according to relevance and selected the top words in each category.

2.4. Social Media Similarity

We compared the frequencies of the comments by categories across four platforms. Using cosine similarity, we measured the similarity between each pair of platforms with respect to the anti-vaccine arguments. Cosine similarity provides a score between zero and one, where a score of one represents identical distributions of categories in the two platforms and zero represents no similarity. The measure is often used to determine similarity in text analysis [35]. The Cosine similarity between two platforms is defined as:

$$\cos(x,\ y) = \frac{\sum_{i=1}^{N} x_i y_i}{\sqrt{\sum_{i=1}^{N} x_i^2}\sqrt{\sum_{i=1}^{N} y_i^2}}$$

where x and y are fixed-length vectors of frequencies of the anti-vaccine categories ($N = 14$) on the first and the second platform, respectively, normalized by the total number of anti-vaccine comments on this platform. Elements of the vectors are denoted by x_i and y_i.

In the next step, we tested the hypothesis that the proportions of anti-vaccine arguments across four platforms are the same using the chi-square test of homogeneity. We removed the categories where the expected values of cells in pairwise comparisons are 0. In post-hoc procedure, we used Bonferroni correction for pairwise comparisons.

3. Results

3.1. Data Overview

Table 1 presents the number of comments from each platform in the final data set, their total number of reactions, and average length as measured by the number of words in the comment. Facebook and Instagram users write the longest comments about COVID-19 vaccination, averaging 2.5 times longer than those created by TikTok users. The most popular comments on Instagram receive approximately five times fewer reactions compared to the other analyzed social media platforms.

Table 1. Number of reactions and the average length of the comments included in the study.

Platform	Number of Comments	Sum of Reactions	Average Comment Length (in Words)
Facebook	250	39,960	30
Instagram	250	6918	32
TikTok	250	34,865	12
Twitter	250	32,449	22

3.2. Categories of Comments

We found that the themes of the comments regarding COVID-19 vaccines could be divided into 15 categories, 14 negative and one positive, as presented in Table 2. Anti-vaccine content is present in 73% of the most popular social media comments about vaccination. Anti-vaxxers mainly declare that they would not be vaccinated because of their inherent freedom of choice. In addition, they often distrust the government and accuse vaccines of being dangerous to health, ineffective, or inadequately tested. Table 3 presents all categories, with examples of original comments from the final data set.

Table 2. Categories of COVID-19 vaccine-related comments on social media platforms.

Category	Description	Count	Fraction
0	Positive attitude	271	0.271
1	I do not want to be vaccinated, because I have freedom of choice	156	0.156
2	Lack of trust in the government	116	0.116
3	The vaccines are dangerous to health	102	0.102
4	The vaccines do not work	85	0.085
5	The vaccines are not adequately tested, were developed too quickly	84	0.084
6	Criticizing boasting about being vaccinated	43	0.043
7	Public figures vaccinated with inert substances (e.g., saline)	36	0.036
8	Conspiracy theories, hidden vaccine effects (e.g., chips)	27	0.027
9	Poster profiting from the encouragement of vaccination	21	0.021
10	COVID-19 disease is not dangerous to health	20	0.020
11	No one is responsible for the potential side effects of the vaccine	13	0.013
12	The vaccine was created only for profit by pharmaceutical companies	12	0.012
13	Better to treat COVID-19 than to vaccinate	9	0.009
14	Natural methods of protection against the disease are better than vaccines	5	0.005

Table 3. Examples of comments by categories and keywords.

Category	Description	Keywords	Example
0	Positive attitude	vaccination, vaccinate, dose, get, people, second	I got a first dose on Friday, and on 1.07, I will get second dose, I love vaccines.
1	I do not want to be vaccinated, because I have freedom of choice	vaccinate, choice, freedom, never, get, everyone	I would never get the vaccine because freedom has no price.
2	Lack of trust in the government	people, lie, gift, anymore, pinocchio, propaganda	And you, a politician, fell for the propaganda. Well, either naivety or lack of knowledge, or you are deliberately lying to all of us.
3	The vaccines are dangerous to health	die, death, people, heart, get, complication	I know two people with severe complications from the vaccine. I also know 3 cases of death by stroke/heart attack among young people.
4	The vaccines do not work	protection, data, infect, dose, basis, get	Data show that the vaccine does not protect against anything.
5	The vaccines are not adequately tested, were developed too quickly	experiment, test, medical, vaccine, pig, guinea	I will never be vaccinated because I am not a guinea pig who can be vaccinated with something not tested.
6	Criticizing boasting about being vaccinated	brag, understand, advertise, sympathize, publicly, celebrity	It's nothing to brag about.
7	Public figures vaccinated with inert substances (e.g., saline)	vitamin, saline, syringe, placebo, teleconsultation, inoculate	Just curious, did he get the same as others or saline?
8	Conspiracy theories, hidden vaccine effects (e.g., chips)	normality, cover, weirdos, warning, victim, unprecedented	That five-year-old who already died overseas is not enough of a warning? How do you know these children are not just being sterilized?
9	Poster profiting from the encouragement of vaccination	pay, traitor, stink, much, advertising, ad	How much did they pay you to advertise this?
10	COVID-19 disease is not dangerous to health	virus, alive, similar, global, evolution, topic	I am still without the vaccine and still alive.
11	No one is responsible for the potential side effects of the vaccine	responsibility, raid, composition, manufacturer, responsible, compensation	No one is responsible. Neither the manufacturer nor the insurance companies wash their hands of the problem.
12	The vaccine was created only for profit by pharmaceutical companies	pharmaceutical, viruses, interested, diet, widely, revenue	You care primarily about the revenue of pharmaceutical companies.
13	Better to treat COVID-19 than to vaccinate	medication, amantadine, condition, mess, authoritarianism, treatment	Why is the study on the efficacy of amantadine in the treatment of COVID-19 moving forward surprisingly slowly?
14	Natural methods of protection against the disease are better than vaccines	natural, vaccinophobia, sugar, recovered, preach, junk	Wouldn't it be better to promote a healthy lifestyle without sugar, junk food to boost natural immunity?

Calculating the relevance of the terms, we proved that the categories could be differentiated by specific sets of keywords, as presented in Table 3. The consistency of the categories and keywords showed that our assignment of the comments to categories was semantically coherent. Words specific to Polish discourse require an additional description. The word "Pinocchio" refers to the Polish prime minister and is associated with public accusations of his frequent lies. Amantadine is considered a miracle drug against COVID-19, similarly to ivermectin in other countries.

3.3. Differences among Social Media Platforms

Figure 1 shows each category's level of popularity on the analyzed social media platforms. The highest proportion of anti-vaccine comments is found on Twitter and the lowest on Instagram. There are differences in the anti-vaccine arguments between users of social media platforms. Anti-vaxxers on TikTok mainly focus on the issue of freedom of choice (Category 1). Conversely, anti-vaccine Facebook and Twitter users focus on similar categories of arguments, primarily emphasizing their lack of trust in the government and pointing out that vaccines are dangerous to health or ineffective (Categories 2, 3, and 4). Instagram users are more likely than others to believe that vaccines are poorly tested (Category 5) and often criticize the public's praise about being vaccinated (Category 6), despite Instagram being a platform designed to share moments from everyday life.

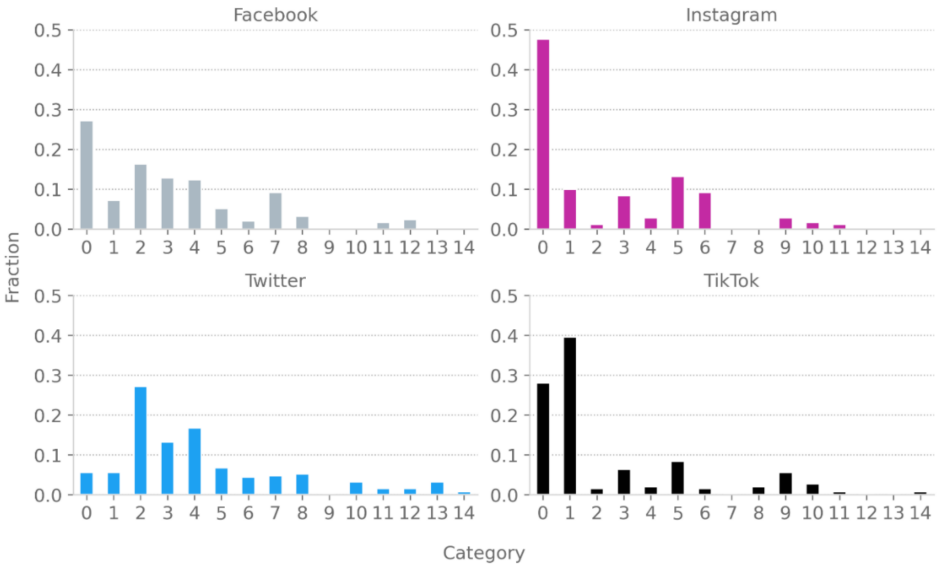

Figure 1. Share of each category of comments by social media platform.

There is a specific argument on Facebook and Twitter stating that important people (politicians, celebrities, etc.) do not use the real vaccine but only inert substances such as saline or vitamins (Category 7). Interestingly, this argument is almost absent on other platforms. Instagram and TikTok contain another specific anti-vaccine theme in which influencers are accused of promoting vaccination for profit (Category 9). Facebook and Twitter users do not use this type of argument, but they tend to use conspiracy theories involving a worldwide conspiracy or chips embedded in vaccines (Category 8).

Topics suggesting that COVID-19 disease is not dangerous to health, no one is responsible for the vaccine's potential side effects, and that the vaccines were created only for profit by pharmaceutical companies are discussed less frequently (Categories 10, 11, and 12).

There are also rare arguments suggesting that vaccinations are unnecessary because it is better to use drugs with unproven effectiveness during infection (e.g., amantadine or ivermectin) or to use natural methods to increase immunity (e.g., a healthy lifestyle) (Categories 13 and 14).

We measured the degree of similarity in the distribution of types of anti-vaccination comments between platforms using cosine similarity. Figure 2 illustrates the pairwise scores. A score of 1 indicates perfect similarity between two platforms, whereas a score of 0 represents no similarity. Anti-vaxxers on Facebook and Twitter use the same comment categories with similar frequency, whereas TikTok and Twitter are most dissimilar.

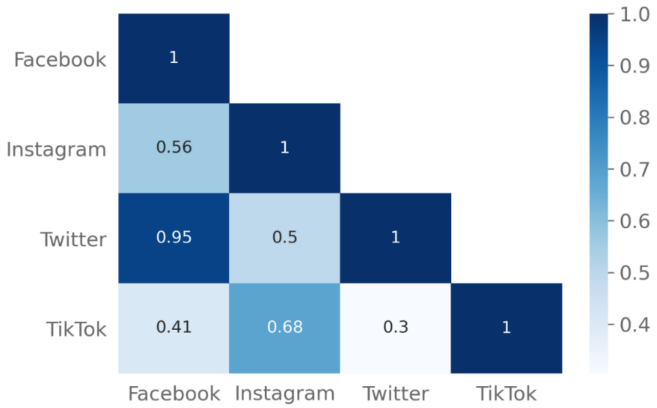

Figure 2. The matrix of cosine similarity scores of anti-vaccine comments' distributions between social media platforms.

We used the chi-square test of homogeneity to determine whether the platforms differ in distributions of anti-vaccine arguments. As the expected counts in the chi-square test cannot take values equal to 0, we removed two anti-vaccine arguments from the analysis: 9 and 13. A significant test statistic ($\chi^2 = 357$, $p < 0.001$) indicates that the proportions of different anti-vaccine arguments are not equal across the four platforms. To indicate for which platforms the differences occur, we conducted post-hoc pairwise comparisons with Bonferroni correction. It revealed that the differences between Facebook and Twitter are not statistically significant ($p = 0.344$). The differences between Facebook and Instagram ($p < 0.001$), Facebook and TikTok ($p < 0.001$), Instagram and TikTok ($p < 0.001$), Instagram and Twitter ($p < 0.001$), and TikTok and Twitter ($p < 0.001$) are statistically significant.

4. Discussion

4.1. Empirical Setting

Our study took advantage of the high take-up of the hashtag "#szczepimysie" (English translation: "#wevaccinateourselves") across many social media platforms. The Polish government created this hashtag to promote the vaccination campaign against COVID-19. In practice, it has become a universal hashtag commonly used to discuss vaccination against COVID-19, both among supporters and opponents. This situation created a unique opportunity to examine the uniform content across different social media platforms. There are various other popular and often English-based hashtags, but they do not provide such uniformity and comparability of content. For instance, "#vaccine" or "#COVID19" are viral in English-language social media but do not reference only COVID-19 vaccination [36,37]. In contrast, the hashtag "#COVID19Vaccine" is specific to COVID-19 vaccines. However, it contains almost only positive content regarding vaccination. This may be due to the policies of combating disinformation and fake news introduced on Facebook, Twitter, Instagram, and TikTok [38,39]. Although these solutions do not completely eliminate the

activity of anti-vaccine movements on social media, they distort the analysis of anti-vaccine sentiment [40,41]. Since the fight against misinformation on social media is much less effective in languages other than English, non-English anti-vaccine content is less distorted by the censorship of social media platforms [39].

Another advantage of using a Polish-language hashtag is the uniformity of users. It is used only in Poland, so every Polish-speaking user writes about the same national policy on vaccination against COVID-19. The analysis of English-language hashtags makes cross-platform analysis difficult, as they are used by people from different countries with different experiences and vaccination availability. Only Twitter allows filtering data by geographical location. In addition, previous studies describing sentiment toward vaccination in Poland [2,42] have shown a high convergence of anti-vaccine topics with other countries [1,3,4,18].

Table 4 presents the sociodemographic data on Polish users of Facebook, Twitter, Instagram, and TikTok [43–46]. TikTok and Instagram have the youngest population with a predominance of women. Twitter and Facebook, which are mostly analyzed in the current literature, have different sociodemographic characteristics, with a large group of their users over 35 years of age. In addition, men are predominant among Twitter users. All analyzed platforms require users to be 13 years of age or older to create an account following their regulations; there are no specific rules in Polish law. However, these restrictions are often only theoretical, and many younger children actively use social media [47].

Table 4. Gender and age of Polish social media users.

	Facebook	**Twitter**	**Instagram**	**TikTok**
men	46%	62%	43%	20%
women	54%	38%	57%	80%
0–24 years	30%	18%	44%	74%
25–34 years	25%	23%	30%	20%
35–44 years	20%	20%	16%	5%
45–54 years	12%	16%	6%	0.5%
55+ years	13%	23%	4%	0.5%

4.2. Anti-Vaccine Arguments on Social Media

Our analysis showed that anti-vaxxers on social media use a limited pool of arguments against COVID-19 vaccines. The most popular argument posits personal freedom of choice, whereby users inform in short messages that they do not want to be vaccinated. This attitude may be triggered by psychological reactance. Reactance is a motivational state that may arise in people with low tolerance for impingements on their freedoms in response to excessive incentives (i.e., persuasive messages sent by the state authorities) [48]. The second most popular anti-vaccine argument concerns distrust toward the government. The government responsible for the vaccination campaign is accused of being unable to deal with the pandemic. It is also alleged that the government is working for the benefit of pharmaceutical corporations, not the public. This is in line with research that has shown that trust in the government influences willingness to vaccinate against COVID-19 [49].

Other arguments concern distrust toward the vaccine's efficiency or safety. Disbelief regarding the efficiency of the vaccine is reflected in ironizing about the number of necessary booster vaccinations to be taken in the future or arguments that people can still get sick despite being vaccinated. Users who doubt the safety of the vaccine focus on side effects (such as thrombosis or myocarditis [50,51]). A related argument is that the vaccines were inadequately tested or that some side effects may appear months or years after vaccination, like in the case of fast development of the swine flu vaccine [52]. Safety is a common concern among anti-vaxxers, which may be due to insufficient transparency of COVID-19 vaccine trials [53].

A group of anti-vaccine arguments refers to allegations of excessive sharing of private lives and accusations of paid promotion. These arguments are directed at the people who

show that they were vaccinated or encourage others to get vaccinated, and it is especially popular on Instagram. It is an interesting phenomenon given the widespread use of social media to share personal lives. This attitude may result from anti-vaccine users' belief that social media influencer marketing is highly effective [54]; thus, they attempt to discredit those who encourage vaccination.

Another group of comments downplays the dangers of COVID-19. Despite the statistics showing many hospitalizations and deaths caused by COVID-19 [55], some anti-vaxxers believe that the disease is not so dangerous as to require vaccination. Conversely, others believe that it is better to use drugs that are not registered to treat this disease (e.g., amantadine or ivermectin) than to prevent it. At first glance, there is an inconsistency in the fact that anti-vaxxers who distrust science want to take other medical substances with less evidence than the vaccines. However, some anti-vaxxers are not only against the vaccines, but also create a complex alternative narrative of the pandemic. These conspiracy theories in such narratives may be inconsistent but are tied together by a belief that the government hides the truth [56]. Another argument suggests that natural methods of boosting immunity and treatments are better than immunization. Natural medicine is often preferred by people committed to environmentalism and interested in spirituality or personal growth psychology [57]. However, natural treatment methods in the case of COVID-19 may delay the implementation of an effective and scientifically proven therapy.

There are also arguments that directly lash out at the pharmaceutical corporations producing the vaccines against COVID-19. Some comments claim that the vaccines were created only for corporate profits, not for the population's health. These assumptions are based partly on the Pfizer financial report for 2021, which revealed $81 billion in revenue, out of which $37 billion was the revenue from the sale of the Comirnaty vaccine [58]. The allegations also include the argument that corporations are not responsible for the side effects despite large profits. However, they do not mention creating enough worldwide compensation funds for adverse effects of the vaccines such as the WHO's compensation program for 92 low- and middle-income countries [59].

4.3. Comparison of Social Media Platforms

There are substantial similarities in the distribution of anti-vaccine arguments on Twitter and Facebook. First, on both platforms, users express strong distrust toward the government. The anti-government narrative is especially apparent on Twitter, which has a stronger political orientation than Facebook [60]. Second, Facebook and Twitter users often express disbelief in the safety or efficiency of vaccination. These similarities may be due to the similar age structure, with a higher proportion of older people compared to other platforms, as presented in Table 4.

TikTok and Instagram include a younger population, mainly generations Y and Z [61,62]. TikTok involves the youngest population studied. Their anti-vaccine comments are generally short and emphasize personal freedom. This finding is consistent with research showing the development of rebellion and a desire for autonomy in adolescents [63]. Although the distribution of anti-vaccine comments on TikTok is highly independent of Twitter and Facebook, there are similarities with Instagram. Users on Instagram and TikTok complain that COVID-19 vaccines are improperly tested. This may be related to the young age of users on these platforms for whom individual safety and long vaccine testing are more important than the population's health, since they do not belong to the at-risk group due to the fact of their age. The anti-vaxxers on TikTok and Instagram also often accuse users promoting vaccines of creating sponsored content. As the marketing content is generally widespread on those platforms [64], anti-vaxxers may be more willing to believe that all content promoting vaccination on TikTok and Instagram is sponsored.

4.4. Practical Implications

We have found that regardless of platform, anti-vaxxers on social media use a consistent set of fourteen arguments against COVID-19 vaccines. However, the popularity

of anti-vaccine arguments varies on different social media platforms. Because different socio-demographic groups are susceptible to different anti-vaccination arguments, multiple platforms should be examined simultaneously in future social media research. It is crucial to pay more attention to adolescents who use other social media platforms and express different vaccination concerns than adults.

Future educational campaigns should consider these differences and encourage vaccinations individually, considering the popularity of specific anti-vaccine arguments on various social media platforms. For example, TikTok users mainly doubt personal freedom, so independent entities, not government units, should conduct information campaigns. These differences should also be considered by public figures active in social media. For example, politicians and government entities who are active on Facebook and Twitter should focus more on messages that build trust in the governmental strategy to fight the pandemic (i.e., being transparent, showing capability) because users of these platforms show little confidence in the government and often accuse politicians of not vaccinating themselves. Robertson C. et al. [65] proved that politicians' messaging endorsing the COVID-19 vaccines can increase uptake among those who identify with that speaker. Information campaigns should also take into account that positive messaging promoting community protection provided by vaccines has a stronger impact on users' willingness to vaccinate than messaging promoting only personal safety [66].

4.5. Limitations

The main limitations concern the sample of comments. First, we analyze the comments from one country published under one hashtag. The hashtag, which is used both by pro- and anti-vaxxers, gave us a unique opportunity to compare the sentiment on four different social media platforms; however, the distributions of comments' categories on platforms can be different under other hashtags. Secondly, we categorized only the top comments with the highest number of reactions. As a result, there is a risk that we have omitted anti-vaccination topics, which are very rare and currently not popular but may become important in the future. For example, Baines A. et al. showed that Parler users are concerned that children are vaccinated without parental consent [67]. Such an argument did not appear in our data set. Thirdly, the opinions on social media do not strictly represent public opinions because negative information spreads faster than positive [68,69]. For this reason, the proportion of anti-vaccine comments on social media may be higher than the number of vaccine opponents in society.

5. Conclusions

Anti-vaxxers on social media use 14 categories of arguments against COVID-19 vaccines. However, their frequency varies on different social media platforms. The activity of opponents of vaccines on Facebook and Twitter is similar, focusing mainly on distrust of the government and allegations regarding vaccination safety and effectiveness. On TikTok, anti-vaxxers mainly focus on their personal freedom. On Instagram, users encouraging vaccination encounter accusations that they are paid or that vaccination is a private matter that should not be shared on social media. Due to the differences in vaccine sentiment among users of different social media platforms, future research and educational campaigns should consider these distinctions and focus on multiple social media platforms. Taking into account the sociodemographic diversity and different susceptibilities to particular anti-vaccine arguments among users of various social media platforms is crucial for understanding the actual attitudes toward vaccination in society.

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8. Oświadczenia współautorów

Warszawa, 08.08.2023

Dominik Wawrzuta

(imię i nazwisko)

OŚWIADCZENIE

1. Jako współautor pracy pt. „Characteristics of Antivaccine Messages on Social Media: Systematic Review" oświadczam, iż mój własny wkład merytoryczny w przygotowanie, przeprowadzenie i opracowanie badań oraz przedstawienie pracy w formie publikacji stanowi: opracowanie koncepcji badania, zbieranie danych, analiza danych, krytyczna analiza wyników, napisanie manuskryptu oraz jego korekta w trakcie recenzji.

   Mój udział procentowy w przygotowaniu publikacji określam jako 80 %.

2. Jako współautor pracy pt. „What Arguments against COVID-19 Vaccines Run on Facebook in Poland: Content Analysis of Comments" oświadczam, iż mój własny wkład merytoryczny w przygotowanie, przeprowadzenie i opracowanie badań oraz przedstawienie pracy w formie publikacji stanowi: opracowanie koncepcji badania, zbieranie danych, statystyczna analiza danych, krytyczna analiza wyników, napisanie manuskryptu oraz jego korekta w trakcie recenzji.

   Mój udział procentowy w przygotowaniu publikacji określam jako 80 %.

3. Jako współautor pracy pt. „Social Media Sharing of Articles About Measles in a European Context: Text Analysis Study" oświadczam, iż mój własny wkład merytoryczny w przygotowanie, przeprowadzenie i opracowanie badań oraz przedstawienie pracy w formie publikacji stanowi: opracowanie koncepcji badania, zbieranie danych, statystyczna analiza danych, krytyczna analiza wyników, napisanie manuskryptu oraz jego korekta w trakcie recenzji.

   Mój udział procentowy w przygotowaniu publikacji określam jako 80 %.

4. Jako współautor pracy pt. „Attitudes toward COVID-19 Vaccination on Social Media: A Cross-Platform Analysis" oświadczam, iż mój własny wkład merytoryczny w przygotowanie, przeprowadzenie i opracowanie badań oraz przedstawienie pracy w formie publikacji stanowi: opracowanie koncepcji badania, zbieranie danych, statystyczna analiza danych, krytyczna analiza wyników, napisanie manuskryptu oraz jego korekta w trakcie recenzji.

   Mój udział procentowy w przygotowaniu publikacji określam jako 70 %.

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(podpis oświadczającego)

Warszawa, 08.08.2023

Mariusz Panczyk

(imię i nazwisko)

OŚWIADCZENIE

1. Jako współautor pracy pt. „Characteristics of Antivaccine Messages on Social Media: Systematic Review" oświadczam, iż mój własny wkład merytoryczny w przygotowanie, przeprowadzenie i opracowanie badań oraz przedstawienie pracy w formie publikacji stanowi: udział w opracowaniu koncepcji badania, krytyczna analiza wyników, nadzór merytoryczny.

   Mój udział procentowy w przygotowaniu publikacji określam jako 10 %.

2. Jako współautor pracy pt. „What Arguments against COVID-19 Vaccines Run on Facebook in Poland: Content Analysis of Comments" oświadczam, iż mój własny wkład merytoryczny w przygotowanie, przeprowadzenie i opracowanie badań oraz przedstawienie pracy w formie publikacji stanowi: udział w opracowaniu koncepcji badania, krytyczna analiza wyników, nadzór merytoryczny.

   Mój udział procentowy w przygotowaniu publikacji określam jako 10 %.

3. Jako współautor pracy pt. „Social Media Sharing of Articles About Measles in a European Context: Text Analysis Study" oświadczam, iż mój własny wkład merytoryczny w przygotowanie, przeprowadzenie i opracowanie badań oraz przedstawienie pracy w formie publikacji stanowi: udział w opracowaniu koncepcji badania, krytyczna analiza wyników, nadzór merytoryczny.

Mój udział procentowy w przygotowaniu publikacji określam jako 10 %.

4. Jako współautor pracy pt. „Attitudes toward COVID-19 Vaccination on Social Media: A Cross-Platform Analysis" oświadczam, iż mój własny wkład merytoryczny w przygotowanie, przeprowadzenie i opracowanie badań oraz przedstawienie pracy w formie publikacji stanowi: udział w opracowaniu koncepcji badania, krytyczna analiza wyników, nadzór merytoryczny.

   Mój udział procentowy w przygotowaniu publikacji określam jako 10 %.

Jednocześnie wyrażam zgodę na wykorzystanie w/w pracy jako część rozprawy doktorskiej lek. Dominik Wawrzuta.

Mariusz Pawczyk

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(podpis oświadczającego)

Warszawa, 08.08.2023

Joanna Gotlib

(imię i nazwisko)

OŚWIADCZENIE

1. Jako współautor pracy pt. „Characteristics of Antivaccine Messages on Social Media: Systematic Review" oświadczam, iż mój własny wkład merytoryczny w przygotowanie, przeprowadzenie i opracowanie badań oraz przedstawienie pracy w formie publikacji stanowi: udział w opracowaniu koncepcji badania, krytyczna analiza wyników, nadzór merytoryczny.

   Mój udział procentowy w przygotowaniu publikacji określam jako 5 %.

2. Jako współautor pracy pt. „What Arguments against COVID-19 Vaccines Run on Facebook in Poland: Content Analysis of Comments" oświadczam, iż mój własny wkład merytoryczny w przygotowanie, przeprowadzenie i opracowanie badań oraz przedstawienie pracy w formie publikacji stanowi: udział w opracowaniu koncepcji badania, krytyczna analiza wyników, nadzór merytoryczny.

   Mój udział procentowy w przygotowaniu publikacji określam jako 5 %.

3. Jako współautor pracy pt. „Social Media Sharing of Articles About Measles in a European Context: Text Analysis Study" oświadczam, iż mój własny wkład merytoryczny w przygotowanie, przeprowadzenie i opracowanie badań oraz przedstawienie pracy w formie publikacji stanowi: udział w opracowaniu koncepcji badania, krytyczna analiza wyników, nadzór merytoryczny.

   Mój udział procentowy w przygotowaniu publikacji określam jako 5 %.

4. Jako współautor pracy pt. „Attitudes toward COVID-19 Vaccination on Social Media: A Cross-Platform Analysis" oświadczam, iż mój własny wkład merytoryczny w przygotowanie, przeprowadzenie i opracowanie badań oraz przedstawienie pracy w formie publikacji stanowi: udział w opracowaniu koncepcji badania, krytyczna analiza wyników, nadzór merytoryczny.

   Mój udział procentowy w przygotowaniu publikacji określam jako 5 %.

Jednocześnie wyrażam zgodę na wykorzystanie w/w pracy jako część rozprawy doktorskiej lek. Dominik Wawrzuta.

Prof. dr hab. n. med. i n. o zdr. Joanna Gotlib

Elektronicznie podpisany przez Prof. dr hab. n. med. i n. o zdr. Joanna Gotlib
Data: 2023.08.09 13:02:04 +02'00'

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(podpis oświadczającego)

Warszawa, 08.08.2023

Mariusz Jaworski

(imię i nazwisko)

OŚWIADCZENIE

1. Jako współautor pracy pt. „Characteristics of Antivaccine Messages on Social Media: Systematic Review" oświadczam, iż mój własny wkład merytoryczny w przygotowanie, przeprowadzenie i opracowanie badań oraz przedstawienie pracy w formie publikacji stanowi: udział w opracowaniu koncepcji badania, krytyczna analiza wyników, nadzór merytoryczny.

   Mój udział procentowy w przygotowaniu publikacji określam jako 5 %.

2. Jako współautor pracy pt. „What Arguments against COVID-19 Vaccines Run on Facebook in Poland: Content Analysis of Comments" oświadczam, iż mój własny wkład merytoryczny w przygotowanie, przeprowadzenie i opracowanie badań oraz przedstawienie pracy w formie publikacji stanowi: udział w opracowaniu koncepcji badania, krytyczna analiza wyników, nadzór merytoryczny.

   Mój udział procentowy w przygotowaniu publikacji określam jako 5 %.

3. Jako współautor pracy pt. „Social Media Sharing of Articles About Measles in a European Context: Text Analysis Study" oświadczam, iż mój własny wkład merytoryczny w przygotowanie, przeprowadzenie i opracowanie badań oraz przedstawienie pracy w formie publikacji stanowi: udział w opracowaniu koncepcji badania, krytyczna analiza wyników, nadzór merytoryczny.

   Mój udział procentowy w przygotowaniu publikacji określam jako 5 %.

4. Jako współautor pracy pt. „Attitudes toward COVID-19 Vaccination on Social Media: A Cross-Platform Analysis" oświadczam, iż mój własny wkład merytoryczny w przygotowanie, przeprowadzenie i opracowanie badań oraz przedstawienie pracy w formie publikacji stanowi: udział w opracowaniu koncepcji badania, krytyczna analiza wyników, nadzór merytoryczny.

   Mój udział procentowy w przygotowaniu publikacji określam jako 5 %.

Jednocześnie wyrażam zgodę na wykorzystanie w/w pracy jako część rozprawy doktorskiej lek. Dominik Wawrzuta.

.....

(podpis oświadczającego)

Warszawa, 08.08.2023

Justyna Klejdysz

(imię i nazwisko)

OŚWIADCZENIE

Jako współautor pracy pt. „Attitudes toward COVID-19 Vaccination on Social Media: A Cross-Platform Analysis" oświadczam, iż mój własny wkład merytoryczny w przygotowanie, przeprowadzenie i opracowanie badań oraz przedstawienie pracy w formie publikacji stanowi: udział w opracowaniu koncepcji badania, ocena danych tekstowych, analiza statystyczna, krytyczna analiza wyników, współtworzenie manuskryptu.

Mój udział procentowy w przygotowaniu publikacji określam jako 10 %.

Jednocześnie wyrażam zgodę na wykorzystanie w/w pracy jako część rozprawy doktorskiej lek. Dominik Wawrzuta.

Klejdysz

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(podpis oświadczającego)