MAKING SENSE OF SOCIAL MEDIA FOR PUBLIC HEALTH DECISION-MAKERS
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THE CASE OF CHILDHOOD IMMUNIZATION IN ONTARIO

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Lay Abstract

Immunization efforts are integral to maintaining herd immunity. Over the past two decades, it has been observed that vaccine hesitancy brought forth by vaccine misinformation has led to reduced confidence in vaccines, contributing to declining vaccination rates that have subsequently led to outbreaks of vaccine-preventable diseases. Vaccine misinformation on social media has played a crucial role in exacerbating vaccine hesitancy. Limited research has explored the use of social media in the Canadian context in relation to how vaccine information is communicated, what is being discussed and with whom. The extent to which decision-makers working in the immunization policy arena in Canada consider the role of social media as a tool for addressing vaccine hesitancy in order to increase vaccine uptake is also unclear. Using a mixed methods approach, this study, carried out in Ontario, Canada, illustrates that communities supporting and opposing vaccines operate in silos that do not necessarily communicate with each other through social media. Although decision-makers acknowledge the role of social media in the salience of vaccine hesitancy, they consider social media to be a less feasible method to increase vaccine confidence. By exploring the networks and conversations about vaccination on social media, and by understanding decision-makers' perceptions towards vaccine hesitancy and social media, this study identified gaps between the recommendations for addressing vaccine hesitancy, provincial decision-makers' preference for addressing immunization, and concerns of the vaccine hesitant on social media. These findings can inform the design of public health messaging to increase the public's confidence in vaccines in Ontario.

Abstract

The successful elimination of vaccine-preventable diseases is contingent on high-vaccine coverage rates in targeted populations. The proliferation of vaccine misinformation on social media has led to vaccine hesitancy in the past two decades. A highly contextual phenomenon, areas with an increased prevalence of vaccine hesitancy and vaccine exemption have been shown to correlate with decreased immunization coverage and intermittent vaccine-preventable disease outbreaks worldwide. Although the Canadian government has recommended the use of social media to increase public confidence in vaccines, little documentation exists regarding the perceptions of advisors and decision-makers in policy and communications for immunization towards vaccine hesitancy on social media, and the use of social media to increase public confidence in vaccines in the context of Ontario, Canada's largest province. This thesis employed 3 unique mixed-methods studies to explore the role of social media in addressing the problem of vaccine hesitancy facilitated through misinformation about childhood vaccines in Ontario. The first study is a social network analysis that incorporates sentiment analysis to demonstrate that pro-vaccine and anti-vaccine communities operate in siloes with little interaction with one another. Those interactions that do occur are most commonly facilitated by sentiment and geographic location, rather than profession or affiliation of the social media user. The second study is a mixed methods content analysis illustrating significant differences in user attributes (emotion, medium shared in tweets, direction of information-sharing, and use of Twitter functions) among pro-, neutral, and anti-vaccine Twitter users, suggesting different motivations underlying Twitter use. Qualitative inquiry of links and reasons for negative

vaccine sentiment illustrate the proliferation of pseudo-experts occupying social media, as well as concerns about vaccine safety and mistrust towards the government. The third study complements the first two studies, and uses documents and in-depth interviews with 23 advisers and decisionmakers in policy and communications to illustrate that although vaccine hesitancy is of concern, the use of social media to increase public confidence in vaccines is met with resistance due to a myriad of barriers at all levels of immunization policy and program delivery in the Province of Ontario. Implications for policy and practice of this study include the recognition that a multi-pronged approach is needed to increase the public's confidence in vaccines. Elements of this multi-pronged approach could include: i) commitments to investing in understanding social media's use in informing immunization at all levels of governance and decision-making; ii) the active surveillance of public sentiment and the public's concerns about vaccines on social media using network analysis and content analysis; and iii) the fostering of interdisciplinary collaboration to design interventions that facilitate connectivity between siloes. The implications for future research include the need for continued commitment to the design, implementation, and evaluation of public health interventions on social media in the Ontario context. This study points to the need to pay attention to the behavioral attributes and affordances of social media in order to develop policies, communicative strategies, and programmatic designs that comprehensively address public concerns towards vaccines and, in turn, promote increased confidence in them.

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Abbreviations

AEFI	Adverse Event Following Immunization
AODA	Accessibility for Ontarians with Disabilities Act
BGTD	Biologics and Genetics Therapies Directorate
CAM	Complementary and alternative medicine
CBC	Canadian Broadcasting Company
CCC	Communications Content Contributors
CDC	Centers for Diseases Control
CHC	Community Health Clinic
cEMR	Community Electronic Medical Record
CIC	Canadian Immunization Committee
CIRID	The Centre for Immunization and Respiratory Infectious Diseases
CIRN	Canadian Immunization Registry Network
DHIR	Digital Health Immunization Repository
EAB	External Advisory Board
EMR	Electronic Medical Record (physician clinical electronic medical record)
ESD	Enhanced Surveillance Directives
FNHSO	First Nations Health System Organization
FPT BPP	Federal Provincial Territorial Bulk Purchase Program
HBV	Hepatitis B Virus
HEIA	Health Equity Impact Assessment
HCCA	Health Care Consent Act
HPPA	Health Promotion and Protection Act
HPV	Human Papillomavirus
ICES	Institute for Clinical Evaluative Sciences
ICON	Immunization Connect Ontario
IDPCB	Infectious Diseases Prevention and Control Branch

INGO	International Non-governmental Organization
iPHIS	Integrated Public Health Information System
IRIS	Immunization Record Information System
ISPA	Immunization of the Schools Pupils Act
LHIN	Local Health Integration Network
mIMMS	Mobile Immunization Entry/ Management Tool
MMR	Mumps, Measles, and Rubella
AMoH	Associate Medical Officers of Health
MoH	Medical Officers of Health
MOH	Minister of Health
MOHTLC	Ministry of Health and Long-Term Care
MOHLTC-PHD	Ministry of Health and Long-Term Care, Public Health Division
MP	Member of Parliament
NACI	National Advisory Committee on Immunization
NACRS	National Ambulatory Care Reporting System
NDS	New Drug Submission
NGO	Non-governmental organization
NIS	National Immunization Strategy
OACPH	Ontario Association of Communicators in Public Health
ODBP	Ontario Drug Benefit Program
OGPMSS	Ontario Government Pharmaceutical and Medical Supply Services
OHIP	Ontario Health Insurance Plan
OPHS	Ontario Public Health Standards
PCC	Policy Content Contributor
PEAR	Panorama Enhanced Analytics Reporting
PHAC	Public Health Agency of Canada
PHAS	Population Health Assessment and Surveillance

PHN-CID SC	Public Health Network - Communicable and Infectious Diseases Steering Committee
PHO	Public Health Ontario
PHO-IVPD	Public Health Ontario – Immunization and Vaccine Preventable Diseases
PHR	Personal Health Record (aka Health Portal)
PHU	Public Health Unit
PIDAC-I	Provincial Infectious Diseases Advisory Committee-Immunization
PWGSC	Public Works and Government Services Canada
RNO	Registers Nurse Ontario
ROI	Return on Investment
SNA	Social Network Analysis
SPHPS	Standards for Public Health Programs and Services
VPD	Vaccine Preventable Diseases
US	United States

Glossary of terms

Anti-vaccine	People opposing the use of vaccines.
Public health agency	Public health organizations responsible for the delivery, implementation, and evaluation of public health services at the national/regional/local level. In the context of Canada, the organization responsible for oversight is the Public Health Agency of Canada.
Public Health Units	An official health agency established by a group of urban and rural municipalities responsible for the provision of community health programs in Ontario. There are 36 PHUs in Ontario.
Small World Network	A network that is neither structured or random, it is an in-between network with high clustering and shortest path length between a pair of nodes are smaller than if a network is randomly distributed.
Vaccine denial	The denial of the efficacy and use of vaccination leading to the refusal of vaccination
Vaccine hesitancy	The delay in acceptance or refusal of vaccines despite availability of vaccination services
Vaccine refusal	The refusal of vaccine uptake.
Yellow Card	Ontario Personal Immunization Record to document immunization records

Declaration of Academic Achievement

I, Melodie Yunju Song, declare that this thesis titled, “Making sense of social media –the case of childhood immunization in Ontario” and the work presented in it are my own. I confirm that I conceptualized and designed the protocols for each study with input from my supervisor and committee members. I independently collected, analyzed, and interpreted all the data for each study and wrote the first draft of each chapter in its entirety and then received several rounds of feedback from my supervisor and committee members on how to improve the chapters.

Chapter 1: Introduction

This doctoral dissertation is a sandwich thesis composed of an introductory chapter (chapter 1), which provides the background and overall framing of my thesis topic, aims and methods, three original research chapters (chapter 2-4) and a concluding chapter (chapter 5), which highlights the new knowledge generated from the thesis and its contributions to the field of health policy. This introductory chapter discusses the current challenges in immunization policy with a specific focus on the association between vaccine hesitancy and low coverage rates for childhood vaccines, and the role of social media in both contributing to this problem and its potential resolution. I will then discuss how my dissertation topic, *"Making sense of social media for public health decision-makers – the case of childhood immunization in Ontario"*, aims to address these challenges through three discrete research studies.

The successful elimination of vaccine-preventable diseases is contingent on high-vaccine coverage rates in targeted populations. Recent immunization coverage rates across Ontario and across Canada have shown that some populations are susceptible to outbreaks due to low coverage rates (Public Health Ontario, 2017). Although most Canadian parents are supportive of vaccination, recent surveys have reported that roughly 34% of parents are not sure whether vaccines are safe (Angus Reid Institute, 2015; Dubé et al., 2018) suggesting that vaccine hesitancy -- the refusal or delay of vaccination (Dubé, Vivion, & MacDonald, 2015) -- may be a predictor of under-immunization, and raising concerns within the public health community (Larson, Jarrett, Eckersberg, Smith, & Patterson, 2014). Retrospective studies have shown that although overall vaccine exemption rates are

low, high exemption clusters are correlated to vaccine-preventable disease outbreak clusters after adjusting for demographic variables such as income, population density, proportion of children under 5 years of age, family size, and ethnicity (Atwell et al., 2013; Omer et al., 2008).

The causes of vaccine hesitancy are numerous and complex, and reflect an intermingling of psychosocial, economic and political beliefs at the individual and community level that can create a powerful narrative against vaccines of all types (Dubé, Vivion, et al., 2015). Some studies have shown that metropolitan areas in high-income countries, and households with parents with high educational obtainment, high socioeconomic status, and being female, are correlated with elevated concerns for vaccine safety (Freed, Clark, Butchart, Singer, & Davis, 2010; Larson et al., 2016; Smith & Marshall, 2010; Yang, Delamater, Leslie, & Mello, 2016), while others have shown that males with minimal college education (Tomeny, Vargo, & El-Toukhy, 2017a), partiality to conspiratorial thinking (Lewandowsky, Gignac, & Oberauer, 2013; Stein, 2017), greater freedom of speech on the internet (Venkatraman, Garg, & Kumar, 2015), and feminism (Smith & Graham, 2017) are also correlated with vaccine hesitancy.

Exposure to social media, in particular, has played a major role in the proliferation of anti-vaccine beliefs (Dredze, Broniatowski, Smith, & Hilyard, 2016; Dunn, Leask, Zhou, Mandl, & Coiera, 2015; Majewski & Beger, 2013). While social media can empower individuals searching for health information with a sense of control and increased perceptions of connectivity (Lin & Chang, 2018), cultivate social resources and increase social capital (Ellison, Vitak, Gray, & Lampe, 2014), and enable health professionals to

share accurate vaccine information to the public via blog posts (Bryan, Gunningham, & Moreno, 2018), its unmediated, acritical features can also be misinforming to the public.

Challenges in reducing the spread of vaccine misinformation

In 1991, when Tim Berners-Lee created the first website and made the World Wide Web royalty-free, one could not have anticipated the exponential growth of internet users. Earlier prophetic researchers begun to ask whether the Internet is leading the public to "knowledge or to Babel" (Jadad & Gagliardi, 1998). By 2003, there were 760 million users and 40 million websites (Murphy & Roser, 2018), but it was still methodologically feasible to retrieve and scrape the web to analyze the quality of health information which showed that roughly 45% of clinical information was accurate (Berland et al., 2001; Eysenbach, 2002). In response, many initiatives took root focused on the development of methods for appraising the quality of health information on the web in the early days of the Internet as an attempt to solve the problem of poor-quality medical information (Cline & Haynes, 2001). Fast forward to 2015 with 3.3. billion Internet users and 1.5 billion websites indexed by Google (Internet Live Stats, 2018), it is no longer possible to regulate or appraise the quality of medical information online due to the amount of information being produced and placed online at any given moment. Google, the most powerful search engine, has only been able to index 16% of the entire web and excludes all contents from the dark web (Goodman, 2015). Adding to the complexity are social media platforms, which are often self-contained networks that allow interlinking with other websites and networks that are often not indexed by Google.

Misinformation on social media and its prominence are driven by user demand and

the retention of usership to these platforms, with few public policies in place to regulate them (Gillespie, 2017). Social media platforms prefer to withhold user data, including the traffic and authentication of users in each social media platform, for instance, 66% of link-shares on Twitter are from bots (Wojcik, Messing, Smith, Rainie, & Hitlin, 2018). While social media platforms have taken to moderating content and hashtags and bots of certain purposes, most social media and internet companies seek to sustain its operations and outperform competitors, and as such, welcome any types of in-and out-bound traffic, and are more than ambivalent towards establishing regulations that would inadvertently inhibit revenue growth generated by advertisement. Growing competition presents problematic challenges for technology companies that pursue revenue growth and disregard government agendas, those within public health field included. That is to say, standards that reinforce regulating user-generated content and the authenticity of the content is not entirely against the platform's ethical conduct.

Social media is at the epicenter of the emergence of a communicative culture marked by networked individualism (Rainie & Wellman, 2012) - the notion that people are increasingly networked as individuals rather than embedded in social groups, and affective publics (Papacharissi, 2015) – or the concept that networked individuals are mobilized and connected through the expression of sentiment. Just as social networks in real life influence parents' acceptance of vaccines (Brunson, 2013), online social networks also mirrors that of real-life interaction, but with those who share homophilous traits in ideology, behavior, and preferences (Bessi et al., 2015). Media narrative also undoubtably influences vaccine acceptance and risk perception of outbreaks (Choi, Yoo, Noh, & Park, 2017; Yoo, Holland,

Bhattacharya, Phelps, & Szilagyi, 2010). Media, in the sense of online journalism, has allowed new genres of professionals such as citizen journalists to promote their own agendas and beliefs to the public, for instance, parents' decision to not vaccinate their children amidst the 2013 polio epidemic in Israel was attributable to citizen journalism and the misinformation it has spread (Gesser-Edelsburg, Walter, Shir-Raz, Sassoni Bar-Lev, & Rosenblat, 2016). It is difficult to disentangle whether media narratives have shaped vaccine acceptance or whether parental beliefs have driven their search for vaccine misinformation, but numerous studies have shown that it is a mixture of the two (Attwell & Smith, 2017).

In contrast to the situation described above, health professionals operate in a different context -- one in which professional interests around an issue are informed by new scientific discoveries and related publications, while the public interest is generally static and correlate with media reports (Kostkova, Fowler, Wiseman, & Weinberg, 2013). Even when pro-vaccine content is posted, it lacks transparent authority (Wiley, Steffens, Berry, & Leask, 2017), which takes away a parents' sense of perceived control and elevates anxiety in searching for vaccine information (Hornsey, Harris, & Fielding, 2018). While new regulatory approaches such as mandatory education for parents who refuse vaccination to school-aged children have been legislated in Ontario (Immunizations of School Pupils Act, 2017), and proposed interventions such as early-education in schools and client-centred counselling sessions for parents that facilitate problem-solving and help to overcome ambivalence (Rollnick & Miller, 1995) and offset parents' hesitancy (Leask, 2011; MacDonald & Finlay, 2013), the effects of these interventions are limited to schools,

hospitals, and clinics. Within the limited timeframe of interaction in a clinical setting, there is only so much health professionals can do to counter entrenched beliefs shaped and formed through intricate interactions both online and offline (Costa-Pinto et al., 2017). In short, the public and health professionals operate on different cycles of attention, holding different assumptions about the biosocial and psychological needs of an individual.

Vaccine misinformation on social media – to address or not to address?

Due to growing concerns about the challenges that misinformation spread through social media networks present to evidence-informed decision making in the area of immunization policy, it seems sensible to consider whether social media may be used as a vehicle to promote improved immunization efforts – in part because Ontario has just experienced bouts of measles outbreaks between 2013 and 2014 that are comparably higher in volume than other provinces and thus captured the media and public's attention in relation to outbreaks in the US and around the globe, and also because social media has emerged as a potential platform for extreme ideologies, and the spread of misinformation about vaccines. In 2014, the Advisory Committee for Ontario's Immunization System Review was commissioned by the Chief Medical Officer of Health to conduct the province's first formal review of its publicly funded immunization system (The Advisory Committee for Ontario's Immunization System Review, 2014). One of the core recommendations in the Committee's final report was the need for the Government of Ontario to establish strategies to foster an informed and confident public that sees immunization as a right and a responsibility. This recommendation was subsequently written into the "Immunization 2020" strategic framework developed by the Ministry of

Health and Long-Term Care in 2015, which seeks to create an "informed, confident public" (MOHLTC, 2015, p.10) and to "'up its game' in terms of the use of internet and social media, with the vast majority of the public now obtaining health information online" (The Advisory Committee for Ontario's Immunization System Review, 2014, p.14).

Over the past 10 years, social media use for public health promotion has grown in scale and in scope. A systematic review published in 2014 found that most agencies have used social media as an information-dissemination portal focusing on the promotion of sexual and reproductive health, general health promotion, non-communicable diseases, and mental health promotion (Capurro et al., 2014). It was not until 2016 that the first systematic review of the use of social media for e-governance reported that transparency/accountability, democratic participation, co-production, and evaluation were the four uses of social media by the public health sector, while most practices fell into the category of creating transparency/accountability, such as the provision of information to the public on health affairs, and evaluation, such as that of public health surveillance (Tursunbayeva, Franco, & Pagliari, 2017).

To date, there is no literature looking at vaccine hesitancy that focuses on social media misinformation in Ontario, there is an increasing need to understand the concerns of the public in the context of Ontario regarding vaccine hesitancy in order to design appropriate interventions. In Ontario, the use of social media in public health has been found to lack clear objectives and does not include guidelines that consider the voice of the public, resulting in a compromised capacity to evaluate the sustainability of public health campaigns on social media (Schein, Wilson, & Keelan, 2010). The deficiencies regarding

lack of campaign use on social media are not unique to Ontario. In the European Union, flu vaccine awareness campaigns were found to be lacking in a guiding framework, such as documenting how the types of vaccine information being promoted were developed, and what outcomes after information dissemination were expected (Ohlrogge & Suggs, 2018). Researchers even conclude that the communicative patterns of US federal government science agencies on social media is to "set it and forget it" (Lee & VanDyke, 2016, p.1).

Studies show that government forays into social media mainly focus on creating transparency, seeking input, seeking online/offline interaction, and symbolic presentation of online presence (DePaula & Dincelli, 2018; DePaula, Dincelli, & Harrison, 2017). To ensure the success of integrating social media for governance, public policy scholars emphasize the importance of distinguishing between *social media strategy* – the strategies embedded within a set of communications strategies to achieve the government agency's overall mission and goal, and *social media policy* – the policies that support the social media strategy, including directives for both employee and citizen conduct on government-run social media accounts, interactions on social media, and the resources allocated to the maintenance of any social media accounts held by the government (Bretschneider & Mergel, 2011; Mergel, 2015).

Whether trust with the government can be built using social media needs further investigation, the literature suggests that publics that interact with the government using social media and two-way communicative tools are more likely to trust the government (Park, Kang, Rho, & Lee, 2016). Despite the established benefits of social media uptake for governance, institutionalizing social media in government agencies is fraught with

challenges related to "privacy, security, data management, accessibility, social inclusion, governance" (Bertot, Jaeger, & Hansen, 2012, p.1).

The challenges of using social media to combat misinformation proliferated by social media is a collective experience for the public sector, as social media is one aspect of a collective effort to bring the government and its services online. Vaccine misinformation on social media, wedged between evidence-informed policies and the public's understanding of vaccines, as well as the perception of vaccine hesitancy of advisors and decision-makers in policy and communications in immunization needs to be explored in the context of Ontario.

Overarching research objectives

The overarching aim of the thesis is to understand the role of social media in addressing vaccine hesitancy through misinformation about childhood vaccines in Ontario. This will be addressed through three discrete studies with complementary research objectives. First, a network analysis of social media conversations on childhood vaccination on Twitter allowed me to understand whether vaccine hesitancy is prevalent in Ontario, and whether clusters of people with different vaccine sentiments were visible (chapter 2). Once a network is established, a mixed methods content analysis of social media user attributes (e.g., profession/affiliation, direction of information-sharing, type of medium used, and links) will help us to understand which potential attributes are associated with certain vaccine sentiments (chapter 3). These two chapters provide important exploratory work about who is communicating about childhood vaccination using social media and whether public health agencies and policymakers are present in the conversation on social

media. Finally, I examine whether social media is a feasible platform to increase public confidence in vaccines, paying special attention to the immunization policy environment at large, and the barriers and opportunities to increase vaccine uptake using social media for public health (chapter 4).

The specific objectives of the dissertation are to:

- Identify the prevalence of anti-vaccine sentiment, pro-vaccine sentiment, and neutral vaccine sentiment on Twitter (Chapter 2);
- Construct a network of childhood vaccine-related conversations on Twitter, analyzing the network properties to detect communities, connections, and important nodes (Chapter 2);
- Identify Twitter user attributes and analyze their association with different vaccine sentiments (Chapter 3);
- Identify themes of vaccine refusal in Ontario, as observed on Twitter (Chapter 3);
- Understand Ontario immunization decisionmakers' perceptions towards vaccine hesitancy, the use of social media to increase public confidence in vaccines (Chapter 4); and
- Identify the feasibility of creating a confidence public in vaccines in Ontario through the use of social media (Chapter 4).

The three research studies that comprise this dissertation were conducted between January 2016 and October 2017. Data analysis for chapter 2 and chapter 3 was completed in March 2017, and data analysis for chapter 4 was completed in October 2017. For chapter 2 and chapter 3, data analysis contributed to the understanding of the Ontario vaccine

hesitancy narrative and the interactions of online users regarding childhood vaccination. For chapter 4, in-depth interviews were carried out with 23 policy and communications decisionmakers and advisers in Ontario complemented by document analysis to explore discrepancies between policy recommendation and practice. The research methods are elaborated in each chapter, and relevant appendices can be found at the end of the thesis.

Chapter 2 addresses the first thesis aim. Motivated by the question *"who is talking to whom about childhood vaccination in Ontario?"*, the study retrieved Twitter data from its Standard Streaming API between April 2013 to March 2016, revealing that anti-vaccine sentiment is the second most dominant sentiment following pro-vaccine sentiment in the Twitter-sphere. The second aim is also fulfilled using network theory, by applying social network analysis to construct a network and subsets of networks, we were able to test 4 different models using Exponential Random Graph Models (ERGMs) to explicate factors underlying community formation, namely, by sentiment, and geographic location, and not by profession/affiliation. More importantly, we verified that the collection of Twitter conversations pertaining to childhood vaccination does not happen in a virtual "town-hall" but occur in highly reciprocal sub-communities characterized by different vaccine sentiments resembling a "echo chambers". The identification of Twitter accounts occupying different yet important structural positions (e.g., brokers, influencers, et cetera) highlight that pro-vaccine information-sharing efforts can be maximized by implementing strategies that mobilize, add, or remove accounts to create information exchange between siloes.

Chapter 3 addresses aims 3 and 4 by adding depth to understanding what's being

discussed about childhood vaccination and what the public's concerns are about vaccines. Using a mixed-methods content analysis, the iterative coding process is a reflexive practice built upon several background theories: reasons for vaccine hesitancy (Schmid, MacDonald, Habersaat, & Butler, 2016), the theory of communicative action (Kim & Grunig, 2011) – a notion that communications occur when people perceive an issue to be a problem; the affordance of social media platforms (Bucher & Helmond, 2017) – the idea that platforms influence the way information is produced, shared, and promulgated; and empirical evidence that "images speak louder than words" guided by Vilem Flusser's philosophy that technology will allow imagery/visual communications more dominant in driving public discourse than text (1985). The coding schemes contributed to the typologizing of behavioral attributes (i.e., information of direction-sharing, general emotion, use of Twitter functions) and the inspection of shared media and contents in links. Applying a difference-in-means test, the behavioral attributes of pro-vaccine, the vaccine neutral, and the anti-vaccine, and qualitative analysis of shared medium, links, and themes of vaccine refusal provide contextualized understanding of the concerns towards vaccines specific to Ontario.

Chapter 2 and 3, taken together, use Twitter as a case study to paint a nuanced picture of vaccine hesitancy on social media. Although vaccine hesitancy is a global phenomenon, these studies highlight the importance of grounding public health studies at the local level, and make the case for using network theory *with* content analysis to generate better use of social media data to understand the attributes and characteristics of the online public.

Chapter 4 shifts attention to the second piece of the puzzle – that is, how are policymakers making sense of social media use in an era of vaccine hesitancy? Using Ontario as a case study to remain consistent with the geographic focus in the previous two studies, this study used both document analysis and in-depth interviews to compare and contrast the expectations of using social media to address vaccine hesitancy evident in federal and provincial policy recommendations, and the feasibility of integrating social media at the practical level in the province of Ontario. The key informants, who are advisers to and decision makers for policy and communications related to immunization, shared their experiences of using social media, and their considerations as to whether social media is a feasible platform to increase public confidence in vaccines, paying special attention to the immunization policy environment at large, and the barriers and opportunities to increase vaccine uptake using social media for public health.

The chapters in this thesis make substantive, theoretical, and methodological contributions to our understanding of the use of social media for governance, public health promotion and prevention pertaining to immunization. Substantively, each of the chapters fill key knowledge gaps at the intersection of the use of social media and policy practice for addressing vaccine hesitancy. Social network analysis in chapter 2 facilitated the modelling of factors that influence the exchange of conversations on childhood vaccines on Twitter, the application of social network analysis to understand the factors related to vaccine hesitancy, and interactions of users participating in childhood conversations, with a geographical focus in Ontario. As a collective set of chapters, this study contributes to a deeper understanding of immunization policymaking in Ontario by identifying the

following: first, despite policy recommendations to increase vaccine uptake through the use of social media, it is only being used for information dissemination, and second, policymakers consider education a major contributor to increasing public confidence, yet there is limited awareness that social media conversations are not "townhalls" but rather "echo chambers", and third, to increase the feasibility of designing social media strategies that are reflective of observations of vaccine hesitancy on social media, one needs to be where the conversation is already occurring.

Novel theoretical insights emerge from approaching public health issues such as vaccine hesitancy from a networked mindset. The Twitter-sphere and the affordance of its platform, follows a power-law distribution which is the observation that a fairly small number of people act in central roles (e.g., many followers). This enabled us to identify Twitter users who are uniquely positioned in the vaccine conversation that can create ties between vaccine sentiment clusters. Not only is network theory useful for identifying the interactions between accounts, it also challenges the notion that in order to successfully promote vaccines, one has to know the demographics, such as age, gender, socioeconomic status, and educational attainment, in order to design strategies to improve vaccine confidence, which is particularly challenging to achieve on social media where anonymous and lurking behaviors are common. Chapters 2 and 3 directly challenge this notion of the need to identify the demography of users and demonstrate that understanding the concerns and behavioral attributes of the pro-vaccine, vaccine-neutral, and anti-vaccine are useful and powerful insights that can help formulate campaign strategies on social media. Chapter 4 marries case study with grounded theory to allow themes to naturally emerge from a

constant comparison of patterns between document and key informant interviews – all supportive of the finding that policymakers are challenged by social media in an era of misinformation.

It is important to consider the following characteristics of this case: i) it can be considered an example of an extreme public health topic with respect to the degree of polarization of public opinion on vaccine hesitancy although other public health topics such as water fluoridation, milk pasteurizing and vaping would be similar in the degree of polarization; ii) the social media platform selected for examination is a preferred utility for public health information dissemination by public health agencies, as well, it is one of the active platforms where vaccine hesitancy spread, despite its lower prevalence of anti-vaccine sentiment compared to other social media platforms such as Facebook, YouTube, and Pinterest; and iii) it is a fairly typical case in jurisdictional terms in the sense that public health infrastructures and guidelines for outbreak prevention in Ontario have been established to respond to VPD outbreaks without the inclusion of social media or consideration of public opinion on social media. Using childhood immunization in Ontario as a case study, this thesis adopted a mixed-methods approach in each unique chapter in data collection, application of theory, data analysis and the reporting of results. Insights were generated drawing on multiple data sources such as Twitter, key informants, government documents to provide context and depth to make sense of social media for public health decision-makers.

These studies address gaps in existing literature, with a geographical focus in Ontario, related to: (1) the application of social network analysis to understand the factors

related to vaccine hesitancy, and interactions of users participating in childhood conversations; (2) the contextualization of vaccine hesitancy by measuring the significance of attributes related to vaccine hesitancy (e.g., emotion, medium shared in tweets, direction of information-sharing, use of Twitter function et cetera); (3) the identification of discrepancies between policy recommendations and policymakers' perceptions of the use of social media given the realities of vaccine hesitancy on social media; and (4) taken together, considerations for aligning policy, practice, and the public's concerns about vaccines.

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Chapter 2. Preface

Chapter 2 provides an understanding to vaccine hesitancy, a highly contextual phenomenon that remains unexplored in Ontario on any social media platforms. This is a cross-sectional social network analysis and sentiment analysis of vaccine hesitancy, which includes the collection of Twitter data related to childhood vaccine conversation and the analysis and interpretation of the properties of networks and its subnetworks. The findings from this study, including the application of network analysis and sentiment analysis, provide public health researchers and practitioners with a foundation for further exploration of vaccine hesitant clusters residing on social media. The methodology applied is also useful for identifying public opinion and clusters of other public health misinformation on social media.

I conceptualized the study, led its methodological design, and conducted the data collection, analysis, and write-up. Nathan Lapiere at the Social Media Lab was a consultant during data collection and analysis. Anatoliy Gruzd assisted with the methodological design of the ERG Model as well as critiques to the methodological and theoretical interpretations of the study. Julia Abelson and John Lavis provided feedback on iterative drafts, revision and provided detailed input on the structuring of the study manuscript.

Chapter 2: A Social Network Analysis of Childhood Vaccine Conversations on Twitter in Ontario from 2013-2016

Abstract

Introduction: Twitter is a platform widely used for public health promotion and communication related to vaccines that can also provide a vehicle for the spread of misinformation. The extent to which public health organizations that are proponents of childhood vaccination are engaging in conversations on social media (e.g., Twitter) with organizations opposing vaccination is unknown. This study aims to map these interactions and the measles vaccine narrative more broadly, in Canada. **Objective:** We aimed to measure the prevalence of pro-, anti- and neutral vaccine sentiments expressed, explore the structural properties (i.e., connectivity, clusters, and centrality) of the vaccine conversation network as a whole, as subnetworks, and explore attributes that influence tie-based connections, and identify the influencers, broadcasters, brokers, most popular, and the efficiently positioned accounts based on centrality measures. **Methods:** A Twitter standard search streaming Application Program Interface (API) was used to download aggregate tweets with keywords related to MMR vaccination from April, 2013 to March, 2016. Netlytic was used for text analysis which generated the most common hashtags, words, and mentions in the conversation. The most frequently used words associated with different vaccine sentiments were visualized using a word cloud. Gephi was used to analyze the network properties (i.e., connectivity, clusters, centrality) of the whole network and subnetworks, and to identify accounts that occupy unique positions based on centralities. ERGM was used to explore attributes influencing cluster formation. **Results**: We identified

that 56% of Twitter conversations regarding MMR were pro-vaccine, 28% were anti-vaccine, and 16% were neutral. Social network analysis showed that the vaccine conversation is a centralized network with many high in-degree nodes, as observed by the high connectivity of nodes in surrounding star nodes. Users were more likely to connect with those sharing the same vaccine sentiment and are highly reciprocal within their perspective sentiment cluster. The influencers, the popular, and the brokers are pro-vaccine, while the broadcasters and the efficiently positioned Twitter accounts in the network are mostly anti-vaccine. **Conclusions:** Identifying distinct nodes on Twitter participating in the childhood vaccination conversation is useful for understanding the interactions occurring between pro- and anti-vaccine nodes. Future public health research should explore the role of high-centrality nodes in misinformation networks on social media and their role in bridging the divide between homophilous vaccine sentiment clusters.

Keywords: social network analysis; social media; Twitter; MMR vaccine; childhood vaccination; public health; vaccination

Introduction

While some online interventions have shown promising results for the dissemination of public health messaging (Bennett & Glasgow, 2009), reviews of social media roles in health promotion and interventions related to improving vaccine awareness have so far yielded mostly inconclusive results (Dubé, Gagnon, & MacDonald, 2015; Jarrett, Wilson, O'Leary, Eckersberger, & Larson, 2015; Lim, 2017). More recent studies have demonstrated that internet-based interventions contributed to more positive attitudes towards vaccines among vaccine hesitant parents (Daley et al, 2018) and that algorithmic and social corrections on social media were equally effective in limiting vaccine misperceptions, with corrections occurring in both high and low conspiracy belief individuals (Bode and Vraga, 2018). However, in some cases, a 'backfire effect' has been observed in which the provision of factual information has strengthened anti-vaccine beliefs (Nyhan, Reifler, Richey, & Freed, 2014). Further, social media has been found to enable vaccine opponents to interact and share information without supporting evidence; these individuals are observed to be highly engaged, highly mobilized, and are continuing to attract more followers in their networks (Mitra, Counts, & Pennebaker, 2016; Moran, Lucas, Everhart, Morgan, & Prickett, 2016). As a result, social media can also lead to the spread and entrenchment of vaccine misinformation (Seymour, Getman, Saraf, Zhang, & Kalenderian, 2015), in part attributed to social media's Web 2.0 functionality -- characterized by user-generated content, interactivity, openness, scalability, and a low threshold for participation (O'Reilly, 2007).

Concerns about declining vaccination rates and the growing social media presence

of the anti-vaccination movement have led public health professionals to pay greater attention to social media as a vehicle for public health messaging (Dredze et al., 2016). Over the past decade, there have been instances of influential vaccine opponents[1] whose skepticism towards vaccines have single-handedly led to the suspension of vaccine programs or a decline in vaccine uptake within their respective countries (Butler, 2017). It is now widely documented that the anti-vaccine movement has contributed to a surge of measles outbreaks in Europe, Asia, North America, and Africa (Ahmed et al., 2017; Aquino et al., 2017; Hukic, 2017; Larson et al., 2014; Mohd, Kew, & Moy, 2017; Okuhara, Ishikawa, Okada, Kato, & Kiuchi, 2017; Ward, Colgrove, & Verger, 2017).

From a network perspective, health behaviour decisions are made in the context of interacting and exchanging information from others, through the *"complex contagion*" effect (Centola, 2013; Lerman, Yan, & Wu, 2016; Valente, 2012, 2015) in which behaviours and beliefs are spread through exposures with multiple sources (e.g., community, information sources) surrounding the individual. However, the exchange of information is often confounded by the *"homophily"* effect, which is the tendency for people to gravitate towards others who share similar opinions, hobbies, and upbringings (McPherson, Smith-Lovin, & Cook, 2001). The structure of a network, combined with understanding the nodal attributes, can inform our understanding of how and with whom information is being exchanged, how the width of a network can influence how far news travels, how fast information flows, and how tightly-knit conversations cluster around an

[1] The opponents to vaccines include: the Ukrainian health minister in 2008 (Bachmaha, 2016), a long-time activist mother in Bosnia and Herzegovina (UNICEF, 2009), and a career scientist/doctor in Denmark in 2014.

issue (Haythornthwaite, 1996). In the context of vaccine acceptance, the "networked" component of social media has widespread implications for the beliefs, attitudes, and knowledge towards vaccination. Unlike categorical thinking which views "individuals and collectives as possessing singular, unitary identities rooted in race, class, gender, or sexuality" (Scott, 2002, p.144)", network thinking theorises that social relationships are 'a map of specified ties' made up of nodes (people), ties (also called edges or links), and the directionality of actors' interactions. The content and pattern (e.g., connectivity, clusters, and centralities) of the relationships can reveal the cohesiveness, prominence, range, and brokerage of a network (Haythornthwaite, 1996). Networked thinking reveals what lies beyond the existing categories of inquiry, especially when problems of inquiry have variables with multiple roles and of no hierarchical importance (Scott & Carrington, 2011)

Public health researchers have used social network analysis to observe complex interactions of stakeholders in health organizations (Provan & Milward, 2001), to measure network dynamics of HIV/AIDS service provisions (Kwait, Valente, & Celentano, 2001), to trace the spread of obesity (Rosenquist, Fowler, & Christakis, 2011), and to track the likelihood of depression among friends (Christakis & Fowler, 2007). It has only been in the last 10 years, with the advent of social media and the development of more sophisticated data collection and analysis tools, that this field of research has expanded to observe how online interactions influence offline behavior such as smoking cessation and alcohol use (Huang et al., 2014) or that friends of friends who share anti-vaccine posts on Twitter are more likely to become vaccine hesitant (Dunn et al., 2015).

Social media network analysis involves the exploration of the connectivity and

clustering of actors on a network level, and the centralities of actors at a node level on social media. As such, it can help us understand the phenomenon of vaccine hesitancy and how it might be influenced by online behaviour. The most recent network analysis of online media showed that different vaccine sentiments cluster together, and the vaccine hesitant reside beyond areas that traditional mainstream media would penetrate (Getman et al., 2017). Salathe and Khandelwal were the first to conduct sentiment analysis on influenza vaccines on Twitter to find that 80% are neutral sentiment, 8% are negative, and 11% are positive (2011). In 2013, Love et al collected tweets on all vaccines to find that 30% of the tweets are positive towards vaccines, 16% are negative, and 54% are neutral (Love, Himelboim, Holton, & Stewart, 2013, p. 201). Radzikowski et al aggregated hashtags to create a narrative of vaccination on Twitter, suggesting that keywords such as #CDCwhistleblower, #bigpharma, and #autism are the most popular hashtags on Twitter (Radzikowski et al., 2016). In another study, semantic network analysis on Twitter contributed to our understanding of the scope and variability of current attitudes and beliefs towards vaccines (Kang et al., 2017).

Twitter is a powerful platform for using social network analysis to explore public sentiment and network structures on social media in the area vaccines. It is one of the most popular social media platforms in Canada behind Facebook, YouTube and LinkedIn (Gruzd, Jacobson, Mai, & Dubois, 2018) and follows the model of information diffusion in which ideas, news, and information can be spread quickly without the constraints of a bi-directional followership platform like Facebook[2] (Pastor-Satorras & Vespignani, 2002). It

[2] Facebook has allowed uni-directional followership for public posts shared on user timelines since 2014.

is a text-based platform where users can share news and follow events in real-time, unlike YouTube or Twitch that are heavily video centric, where the discourse of content is dominated by the streamer or content distributor. Twitter has been used extensively by network scholars involved in vaccine research and is heavily used by a key group affected by this topic: 42% of Canadian adults own a Twitter account, with 18-34 year-olds being the most active (Gruzd et al., 2018) – an age group when first-time pregnancies are likely to occur and thus this population would most likely need to make immunization decisions for their newborns or young children.

We used Twitter to explore the MMR vaccine and other childhood vaccine conversations. Despite Canada having eliminated measles in 1998 (Katz et al., 2004), imported cases of measles contributed to outbreaks in areas with low herd-immunity, and 704 cases of measles were reported across the province from 2013 to 2016 (Government of Canada, 2015, 2013, 2016). The federal and provincial government consider an understanding of the public's knowledge, acceptance, and perception towards vaccines an important contributor to increasing vaccine uptake in Canada (Scheifele, Halperin, & Bettinger, 2014).

This study is designed to address four objectives about MMR vaccine and other childhood vaccine conversations during the period of sustained measles outbreaks in Canada's most populous province: measure the prevalence of pro-, anti- and neutral vaccine sentiment expressed; explore the structural properties of the vaccine conversation network, including the connectivity and clustering of the whole network, and of sub-networks

Source: URL: https://www.facebook.com/help/community/question/?id=10201366080253237

partitioned by modularity, sentiment, and profession/affiliation, explain the attributes that influence tie-based connection; and calculate the centralities of each node in the network to identify the influencers, broadcasters, brokers, most popular, and the efficiently positioned Twitter accounts between 2013 to 2016.

Methods

Data Collection

We manually collected messages ("tweets" hereafter) on Twitter using its standard search streaming API over a three-year period (April 2013-March 2016) in Ontario, Canada - a timeframe that corresponded with several measles outbreaks in Ontario and the rest of Canada which directed increased attention to the topic of MMR vaccinations within the public health professional and broader communities.

Two datasets of independently retrieved tweets were created and merged: 1) randomly selected tweets containing any or all of the following keywords: "MMR", "vaccine", "anti-vaccine" and "antivaccine" in Ontario, within a 150-mile radius of Toronto and 2) a comprehensive set of Ontario Public Health Unit (PHUs) tweets related to MMR and other childhood vaccines (and excluding dengue fever, Human Papilloma Virus, Influenza, Hepatitis vaccines, among other adult vaccines). Public Health Units are the 36 geographically defined organizations responsible for the implementation of public health programs in the Province. A comprehensive set of tweets from these accounts would otherwise not have shown up in the standard streaming API, which only displays randomly selected tweets. To avoid skewing the sentiment of the overall network, we excluded identical retweets, if the retweets were from the same Twitter account. Thus, each retweet

is from a unique user. A total of 1,037 tweets were collected. All tweets were manually inspected to remove tweets from bots[3], and those that were not in English. The process yielded 875 tweets from 712 unique users. These tweets were then used to carry out three separate analyses.

The following syntactical features of each tweet were captured: the body, forwarded information in the form of a tweet, weblink, or images and videos from others ("Retweets"), @username in the beginning of a tweet ("Replies"), @username in any point of the body ("Mention"), and keywords initialed with the hashtag symbol ("#").

Data Analysis

Data were analyzed using three discrete techniques (sentiment analysis, network analysis, Exponential Random Graph Modeling) and supporting analytical platforms (Netlytic, Gephi, R). In our analysis, each Twitter account is a node. First, to measure the prevalence of pro-, anti- and neutral vaccine sentiment, a manual sentiment analysis was used to identify the tweets' vaccine sentiment (i.e., neutral (including ambiguous tweets), positive, and negative) and to create a word cloud. The sentiments were coded based on the literature review of sentiment analysis categories on vaccine conversations on social media (Mitra et al., 2016; Salathé & Khandelwal, 2011). We first ran the dataset in a sentiment analysis software called Sentigem, which reported have a 75% accuracy in detecting sentiments in tweets (Cieliebak, Dürr, & Uzdilli, 2013). The software achieved a low accuracy (27%) for detecting vaccine sentiment for our dataset, failing particularly at long

[3] It was necessary to exclude spam accounts that may potentially lead to representational bias in terms of vaccine sentiment. This was achieved by running all bot-like accounts in Botometer, Indiana University. "Botometer by OSoMe.". URL: https://botometer.iuni.iu.edu.

sentences, and erroneously detected general sentiment over vaccine sentiment. Therefore, manual sentiment analysis was carried out rather than using an automated approach because it was better able to capture subtleties (e.g., sarcasm, humour), it could be done efficiently given the relatively small dataset and the ability for multiple codes to be applied simultaneously, and it provided an opportunity for greater familiarity with the dataset. We then used Netlytic (Gruzd, 2016), a social network analysis freeware with built-in text analytics function to create a word count of the most frequently used words within the body of text, including hashtags and account names. The data were then exported to Tableau 9.0 to generate a word cloud based on word count, with colour-coding used to portray different vaccine sentiments.

Following sentiment analysis, we explored the network properties of the whole vaccine network by conducting a social network analysis using Gephi. At the network level, the properties explored included connectivity (diameter, characteristic path length[4], density) and clustering (e.g., clustering coefficient[5]). At the node level, we explored centralities (e.g., degree, betweenness, closeness) of the overall network and 3 partitioned sub-networks were then inspected. (See Appendix 1 for glossary of network analysis terminology). Following these steps, the whole network was furthered partitioned in 3 different ways: first, a partition by modularity using Newman's modularity function (Newman, 2006), which divides the network into interconnected sub-networks to differentiate unified versus divided structures from a range of 0 to 1; second, a partition by

[4] Also called average path length (Strang, Haynes, Cahill, & Narayan, 2017).
[5] Modularity is the reverse of clustering coefficient.

profession/affiliation as coded by the researcher; and third, a partition based on vaccine sentiment (e.g., pro-, anti-, neutral).

The *connectivity* of a network, indicated by diameter, characteristic (or average) path length, and density, shows whether and how fast information will spread in the given network. The diameter of the network is the longest of the all-pairs shortest path lengths from one node to another (Epskamp, 2014); it indicates how fast and wide information travels within the network[6]. The characteristic path length of a network is to be interpreted along with the diameter, density, and betweenness centrality of the network; it is the shortest average distance between any two nodes in the network (Brandes, 2001). The density of a network is calculated by the total number of ties divided by the total number of possible ties, it helps interpret the overall linkage between network actors in knowledge-sharing communities (Müller-Prothmann, 2007).

We measured *clustering* using an average clustering coefficient (Watts & Strogatz, 1998), which reflects "the extent to which friends of *v* are also friends of each other" (p.441) and the clustering of a conversation circle. Ranging from 0 to 1, 1 indicates that every node in the network is connected to every other node. A high clustering coefficient is observed in dense ego networks with "a lot of mutual trust" (Tsvetovat & Kouznetsov, 2011, p.66), and vice versa in "star networks with a single broadcast node and passive listeners" (ibid, p.66).

The centrality of nodes in a bi-directional network (e.g., in-degree, out-degree,

[6] Information tends to travel faster in smaller diameters, however, the wider the diameter, the slower the information travels but the further the reach.

betweenness, closeness) helps us identify where information gets passed on or through the network. Numeric values are calculated for each node, based on the number of ties a node has to other nodes in the network. Degree centrality can help us interpret how well connected a node is in the network - higher degree centrality indicates higher connectivity with others in the network. In-degree centrality indicates popularity, and out-degree centrality indicates the node's capacity as broadcaster (e.g., talkative, spammer), and the overall degree centrality (in-degree and out-degree combined) indicates how influential a node is. In a scale-free network such as social media, nodes usually follow a power-law distribution, the node distribution is not affected by the size of the network, and most nodes have low degree centralities while a few nodes exhibit high degree centrality (Barabasi, 1999) – this is often the type of network shown to diffuse misinformation faster than random networks (Zhou, Liu, & Li, 2007). Betweenness centrality helps us interpret how well a node connects to other nodes. Measured by the number of times a node acts as a bridge along the shortest path between two other nodes, a higher betweenness indicates that a node is more central and connected to others (Freeman, 1978; White & Borgatti, 1994). High-betweenness nodes are crucial to sustaining structural robustness (Yang, Zhu, et al., 2016). Closeness centrality helps us interpret how easy it is to reach other nodes, and is derived from calculating the inverse of the sum of the shortest distance between each node and every other node in the network.

To identify attributes contributing to cluster formation at the node level, we coded two identifiable attributes (i.e., profession/affiliation and geographic location) of the Twitter users. The coder begins by reading the initial tweet, the Twitter user profiles, and

10 of the most recent tweets on each user's timeline to identify their profession/affiliation and geographic location, if the tweet is not geotagged. During the iterative coding process, the coder identified the emergence of professions and affiliations based on the users' profession (if the account belongs to an individual) or affiliations (if the account belongs to an organization) that were qualitatively unique in the vaccine conversation. The result yielded 8 "profession/affiliation" categories. An initial codebook was constructed to ensure the reliability of the coding schemes. The principal researcher conducted all the coding and refers to the codebook[7] to ensure the codes remain consistent throughout the process.

To explain whether the above attributes contributed to the formation of tie-based relations in the network (i.e., cluster formation), we used the "statnet" package in R (Hunter, Handcock, Butts, Goodreau, & Morris, 2008) to test whether the presence of ties in the vaccine conversation was based on network properties and/or user attributes (e.g., vaccine sentiment, location, profession) or by chance alone. Exponential-family Random Graph Models (ERGM) were employed to offer a "statistical framework that captures complicated multilevel structures through network configurations" based on the assumption that "network ties are conditionally dependent" (Wang, Robins, & Matous, 2016, p.125). The construction of multi-level structures is incremental, adding one attribute at a time to measure whether each adds to the formation of tie-based connections. To accomplish this, a null model was constructed (*net~edges*)[8] without any added properties or user attributes, **Model 1** included 2 network properties: reciprocity (*mutual*), which

[7] Codebook is included in the appendices in chapter 3 of the dissertation.
[8] Italics in brackets indicate the R codes used in the statnet package.

indicates responsiveness to each other amongst the vaccine conversation, such as replying to one another's tweets; and centrality (*gwindegree*), which measures the number of users replying to a user. **Model 2** included the user attribute "vaccine sentiment" (i.e., positive, neutral, negative) to explore whether it was significant to the conversation patterns in Model 1. In **Model 3**, we added an additional network property: isolates (*isolates*) to effectively weed out the isolate nodes that are not connected to anyone in the network, and then added the user attribute "region" (i.e., Canada, USA, elsewhere, undisclosed) to measure whether geographic location influences conversation patterns in the network. Finally, we added the user attribute "profession/affiliation" in **Model 4** to measure whether it influences the conversational ties in the network. To test for the accuracy of predictors of the selected properties and attributes, the Aikaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) values were measured. The reduction of both AIC and BIC will indicate that the proposed models were appropriate predictors of tie-based network effects (Butts et al., 2014). A Goodness of Fit (GoF) was also measured to determine the accuracy of model prediction (Hunter et al., 2008).

Finally, we measured the in-degree, out-degree, overall degree, betweenness centrality, and closeness centralities of each node to identify Twitter accounts that are influencers (highest overall degree centrality), broadcasters (highest out-degree centrality), most popular (highest in-degree centrality), brokers (highest betweenness), and the efficiently positioned (highest closeness centrality) in the childhood vaccine Twitter conversation.

Throughout our analysis, we paid careful attention to ethical considerations of

social media data collection. We adhered to the principles of research ethics to "do no harm". All tweets retrieved were publicly available on Twitter's platform[9], and accounts were anonymized and assigned pseudonyms, except those belonging to verified public figures[10]. This study was approved by the Hamilton Integrated Research Ethics Board (HIREB) in November, 2015.

Results

Vaccine sentiment in Twitter conversations

Sentiment analysis shows that 56% (n=400) of the Twitter accounts are pro-vaccine, 28% (n=201) are anti-vaccine, and 16% (n=117) expressed neutral or ambiguous sentiment towards vaccines. We found 73 unique Twitter accounts that were established by individuals dedicated to promoting anti-vaccine sentiment, such as posting, retweeting, and sharing information from one social media platform to another (e.g., sharing websites on Twitter and retweeting other anti-vaccine account's tweets). In contrast, with the exception of Immunize Canada (@ImmunizeCanada), Twitter accounts that expressed pro-vaccine sentiment did not use their accounts for the explicit purpose of promoting vaccines.

Text analysis of the vaccine conversation network (Figure 1)

After deleting common words that do not add meaning to the analysis[11], we found 97 words that were used more than 15 times, including hashtags (#), twitter handles ("*@username*"), and any word in a tweet (Figure 1). As expected, "vaccination", "anti-

[9] Twitter maintains the right to terminate any or all APIs for data retrieval without notice.
[10] This is defined by whether their Twitter accounts are Twitter sticker-verified next to their account handle.
[11] Excluded words: 'the, at, in, what, do, I'

vaccine" [12], and "measles" were frequently mentioned because the query itself contains these words. However, the words "MMR" and "mumps" were not frequently mentioned in the query, suggesting that discussions about vaccination were rarely focused on one vaccine but rather a multitude of vaccines – this is particularly reflected in tweets put forth by public health units (PHUs) - most tweets were about publicly funded vaccine schedules and rarely about MMR vaccine alone.

Both anti-vaccine and pro-vaccination tweets frequently used the following words: #cdnpoli[13], #onpoli/ontpoli[14], health, public, support, video, health, school; they mention or tweet to an anti-vaccine celebrity[15] and then-Minister of Health and Long-Term Care of Ontario, Dr. Eric Hoskins. Pro-vaccine twitter users referred to the name Jenny McCarthy frequently to express dismay and disapproval (e.g, '*that Jenny McCarthy'*). Anti-vaccine users, on the other hand, mentioned Jenny McCarthy in support of her anti-vaccine ideologies (e.g.,*"@JennyMcCarthy witch hunt, support your views #antivaccine, #hearthiswell"*).

We observed many words like "immunization, Ontario, info, questions, students, outbreak" that were used frequently in the pro-vaccine tweets. This is due to the amount of pro-vaccine tweets posted by public health agencies (e.g., provincial and federal and local public health agencies, and related organizations). The word "immunization" is exclusively

[12] And its variant, e.g., antivaccine.
[13] The #cdnpoli hashtag is used to share information on Canadian policies, polls, or politics. "Anatomy of a Hashtag: Who Tweets about Canadian Politics?" Accessed February 28, 2018. https://www.theglobeandmail.com/news/politics/anatomy-of-a-hashtag-who-tweets-about-canadian-politics/article8292353/. Retrieved on January 5th, 2018.
[14] The #onpoli or #ontpoli hashtag is used to share information on Ontario policies, polls, or politics.
[15] Anti-vaccine celebrity from the USA.

used by those who were pro-vaccine, such as in sentences that describe how immunization works, or posts that contain immunization schedules. The words "misinformation" and "movement" were both used to describe the aspects surrounding the antivaccine movement, and are also exclusively used by those who were pro-vaccine. Many pro-vaccine tweets were commentaries on news of outbreaks and the importance of the protection of school-aged students. In terms of hashtags, pro-vaccine tweets used hashtags most frequently during the 3rd week of April, (#measles and #vaccineswork) in support of the Canadian National Immunization Awareness Week.

In contrast, anti-vaccine users did not describe themselves as participating in a "movement"; instead, they use the words "truth", "science", and "study" to question the safety of vaccines (e.g., demanding truth, requesting for more studies to be done, citing pseudoscience, et cetera). They used hashtags such as #nomandates, #CDCwhistleblower, #showupday, and #hearthiswell. The hashtag "no mandates" originated from the California mandate Senate Bill 277 which was introduced to require school-aged children to receive vaccinations before school enrollment. The #nomandate hashtag were used by Canadians, too, upon receiving news that 7,350 students were suspended from school in Ottawa until parents submitted proof of vaccination between December 15th, 2015 and March 1, 2016 (CBC, 2016) to protest the possibility of introducing mandatory vaccination in Ontario. The #CDCwhistleblower hashtag referred to William Thompson, an alleged career scientist from the CDC with no internet presence, who was considered by the anti-vaccine movement to be a symbol of truth that evidence of vaccine safety was tampered with.

Network properties of Twitter's childhood vaccine conversation in Ontario

Whole network connectivity and clustering

Ontario's vaccine conversation network on Twitter during the study period is made up of 718 nodes and 734 edges (Table 1). The network has a diameter of 6, suggesting that 6 steps is the furthest[16] a node is to any other node. It has a characteristic path length of 2.659, meaning that the average "degrees of separation"[17] is 2. The graph density has a density of 0.1%, signifying low connectivity of the overall network. The network has an overall modularity value of 0.831, indicating a network consisting of many clusters with few or no overlaps[18]. Our network likely exhibits properties of a small-world network, such that a network has "high local clustering and short path length" (Humphries & Gurney, 2008, p.1), as it has a clustering coefficient of 0.196[19], which is significantly higher than the clustering coefficient of 0.0016 if it were a random graph[20].

Sub-network clustering and centrality

We identified a total of 111 clusters, but only 8 clusters consisted of more than 2% of all nodes, accounting for 58% of all nodes. The 8 clusters were further grouped into 2 major clusters based on proximity within the layout, and all nodes were color-coded by

[16] Nodes that are not connected to any other node in the network would thus have a characteristic path length of 0 and has a diameter of 0.

[17] The term "6 degrees of separation" that playwright John Guare used to describe that phenomenon that everyone is connected to everyone in the world (1990). The idea stems from Travers and Milgram's study that measured two individuals are distanced by 6 friendship links on average (Travers & Milgram, 1969).

[18] Modularity values higher than 0.4 is considered a meaningful community detection (Blondel, Guillaume, Lambiotte, & Lefebvre, 2008).

[19] This is calculated using an undirected graph using Lapaty's "main memory triangle computations for very large graphs" (Latapy, 2008, p.1), as current methods to assess and measure directed graph clustering coefficients are ineffective in terms of "capturing interconnectedness when asymmetric weighted connections are observed" (Clemente & Grassi, 2018, p.36).

[20] The random graph clustering coefficient is calculated using the average degree of a node divided by the number of nodes minus 1, 1.175/ (718-1) = 0.0016

sentiment and visualized using Fruchterman-Reingold force-directed graph layout algorithm (Fruchterman & Reingold, 1991) (See Appendix 2). Cluster A consists of 16 communities, with an average degree-centrality of 1.37. It includes 3 pro-vaccine nodes with higher degree centrality: Toronto Public Health (@TOpublichealth), Ottawa Public Health (@ottawahealth), and Ontario Public Health[21] (@onthealth). Within cluster A is a high in-degree centrality anti-vaccine node, which we identified as a celebrity personality from the USA, Jenny McCarthy [22] (@JennyMcCarthy). Cluster B consists of 20 communities with an average degree-centrality of 1.44, it includes 5 high out-degree centrality anti-vaccine nodes that were tweeting to other anti-vaccine accounts, retweeting news (neutral and pro-vaccine sentiment), or mentioned by other pro-vaccine accounts. The connectivity of a network is only meaningful at the whole network level for interpretation, but values for connectivity for subnetworks are still reported in Table 1 for reference.

A total of 8 profession/affiliation groups were identified: Official accounts belonging to Ontario PHUs (n=24), public health professionals (n=20), other health professionals (e.g., physicians, nurses, and any licensed health professionals in Ontario) (n=120), celebrities (e.g., actors and actresses, singers, et cetera, with verified Twitter accounts) (n=12), politicians (e.g., verified Twitter accounts belonging to politicians) (n=64), news media (i.e., Twitter accounts of TV, print, radio, and online news channels, and affiliated personalities such as news anchors) (n=133), dedicated anti-vaccine accounts

[21] Ontario's provincial public health agency.
[22] Even though the celebrity is from the United States, she is still considered part of Ontario's vaccine conversation because of her frequently being mentioned in Ontario.

(i.e., Twitter accounts established for the purpose of promoting anti-vaccine messages) (n=73), and the public (i.e., the general public that does not have a vested agenda in vaccine issues but participated in vaccine conversations) (n=224).

The density of the profession/affiliation partitions are lower than the overall network, however, Ontario PHUs and anti-vaccine affiliation partition have a higher density than the rest, which can be interpreted as members having more intra-communication and a potential of staying connected to the topic of interest (e.g., vaccination). All partitions have relatively low clustering coefficients calculated by the number of closed-triangles relative to the potential number of triangles available in the network. This indicates that partitioning by profession/affiliation is not where vaccine conversation cliques form. In model 4 (See Table 2), we detected that a negative likelihood of ties was observed within the same profession/affiliation. This is most pronounced in the public health professional, celebrity, and politician affiliation: the low connectivity of each partition shows that vaccine conversation does not flow intra-group; for instance, celebrities do not talk about vaccines with other celebrities, and as such, they are not easily mobilized as a group when it comes to advocacy for vaccines.

To accompany findings from the ERG Model 4, we partitioned the network by vaccine sentiment, which yielded the finding that neutral sentiment Twitter accounts are the least connected to other neutral sentiment Twitter accounts with a clustering coefficient of 0. In contrast, positive sentiment nodes and negative sentiment nodes are well connected within their own sentiments. The divisibility of networks into clusters, as indicated by modularity (Truong & Kwon, 2017) is highest for those with pro-vaccine sentiment,

followed by anti-vaccine sentiment, and neutral sentiment.

Attributes influencing cluster formation in the network

The ERGM model in Table 2 shows the overall structural features of the network: edges (ties), isolates (nodes that do not connect with others, those with a degree of 0), reciprocity, and centrality (degree); and user attributes: vaccine sentiment, region, and profession/affiliation. Model 4, which captures all the variables above, shows that the network has high reciprocity (EST=2.95), and a negative in-degree centrality value (EST=-3.08), suggesting the presence of high-centrality nodes around which clusters form and the finding that users' tendencies to reply to one another, was more likely than by chance alone. Users' attributes also have an effect on facilitating network ties: those with positive and negative vaccine sentiment tend to connect within their respective sentiment, while neutral sentiment nodes do not; ties were observed for nodes in Canada or in undisclosed locations, whereas reciprocity was not pronounced for nodes in the US or other countries. To assess the strength of Model 4, we tested the goodness of fit and the observed in-degree centrality, out-degree centrality, and minimum geodesic distance distributions (Figure 2). In the plots, the vertical axis is the relative frequency of nodes (in-degree and out-degree), edges (minimum geodesic distance). The observed statistics in the actual network are indicated by the solid black lines. The grey lines represent the 95% confidence interval of the simulated network. The models slightly over-estimated the average in-degree distribution but captures the shape of the distribution in the original network well, in addition, the overall diagnostics in the lower right quadrant show that the actual network fit within the simulation network.

Accounts derived from centralities of individual nodes

We identified the top influencers (nodes with highest overall degree centrality), the most popular (nodes with the highest in-degree centrality), the broadcasters (based on high out-degree centrality), brokers (highest betweenness centrality), and the efficiently positioned (highest closeness centrality) based on various centrality measures (See Appendix 3). Public accounts consisted of public health agencies and physicians, and "The View"[23] which is neutral in sentiment, as well as a vocal anti-vaccine US celebrity. A number of anonymized Twitter accounts included members of the public who are vocal against vaccination, such as mothers of children with autism, and a nutritionist who is avidly anti-vaccine and chairs the VaccineChoice.ca coalition.

There were a number of public Twitter accounts that have higher in-degree, which is interpreted as being more popular and sought after in the Twitter conversation. In contrast, those with negative sentiment were information 'broadcasters' who initiate connections with others (e.g., tweeting at someone, mentioning someone, et cetera), as calculated by nodal out-degree centrality. Out-degree and in-degree centrality informs how influential a node is, and the top 3 influencers in Ontario were pro-vaccine, followed by Jenny McCarthy and The View. PHUs, the Minister of Health and Long-Term Care in Ontario and an avid pro-vaccine physician, not affiliated with any immunization decision-making agencies, are considered 'brokers'. This means that they had a high betweenness calculated by forming the shortest pathway in the network, thus are considered information

[23] A TV show broadcasted by American Broadcast Company (ABC) in the US that targets female viewers to discuss politics, entertainment, and any daily news. The View is broadcasted by CTV on cable TV in Canada.

gatekeepers that bridge disparate communities in the network. Finally, accounts that had high closeness centrality were considered 'efficiently positioned' because they were closer to all other nodes and make efficient broadcasters in a network. There are 3 anti-vaccine nodes and 2 pro-vaccine nodes in this position.

Most PHUs tweeted or relayed information about vaccination, however, they did not engage with others and thus their position was marginal compared to more active nodes with higher centralities. Overall, except for one PHU in a heavily populated metropolitan area in Ontario, broadcasters and the efficiently positioned were mostly anti-vaccine, including one prominent Toronto-based anti-vaccine author who had son with severe peanut allergy that died following a routine vaccination. The author actively promoted anti-vaccine information by mentioning others, as well as tweeting and retweeting news to stay salient and relevant. Although this author was not influential, she is considered to be a broadcaster, and depending on interpretation, in the position of an "activist" or a "spammer". Three other prominent anti-vaccine Twitter users were identified as Canadians who actively mentioned politicians, celebrities, and PHUs to "warn" them of "vaccine dangers", are efficiently positioned to have the shortest reach to others within the entire vaccine conversation network.

Discussion

Principal findings

Just over half of Ontarians who engage in childhood vaccine conversations on Twitter exhibit pro-vaccine sentiment, while a minority exhibit negative vaccine sentiment and neutral sentiment.

The vaccine conversation network on Twitter in Ontario exhibits small-world properties and consists of clusters that are variable in sentiment. This indicates that the conversation aggregates around a few users, and within the same rather than across different vaccine sentiments. Pro-vaccine and anti-vaccine sentiment clusters have network structures that are somewhat more robust and interactive, compared to neutral sentiment clusters which are spread out and don't form a visible cluster. This is likely due to the fact that neutral clusters consisted of predominantly news media accounts. The ERGM model revealed that those with negative and positive sentiment are more likely to connect with others who share their sentiment, and that the conversation is highly reciprocal within the group, with many high in-degree nodes.

We found that partitioning by the attribute "profession/affiliation" is not the best indicator of identifying clusters, suggesting that the vaccine conversation is not organized around focused interests based on profession or affiliation. The exception is Ontario PHUs and users who only tweet about anti-vaccine issues; these groups exhibited higher within-group density than the rest. This is in part due to their obvious polarization in terms of sentiment, thus intra-communication was more frequently observed than inter-communication with other affiliations. Meanwhile, attributes such as geographical factors play a part in cluster formation in the network: tie formulations are more likely if users are based in Canada, or in undisclosed areas, as opposed to being located in the US or elsewhere. This could be due to the fact that users follow those whom we know in real-life, or people that are in close proximity to us, such that online ties resemble connections we establish in real-life.

Jenny McCarthy was the most influential anti-vaccine account in our dataset, even though she has not tweeted to other people or replied to anyone about vaccination. She remained relevant because of her importance in the anti-vaccine movement in North America at the time of data collection. Four pro-vaccine accounts were network brokers: Toronto Public Health, Ottawa Public Health, Public Health Ontario, and Dr. Eric Hoskins, indicating that their voices in the Twitter-sphere were crucial in terms of bridging dissimilar vaccine sentiments.

Findings in comparison to other research

This study was the first to analyze vaccine sentiment on social media in Ontario. Our findings are consistent with population-level surveys, which have reported that 39% of Ontarians and 41% of Canadians respectively, consider vaccines unsafe (Angus Reid Institute, 2015; Seeman & Rizo, 2010). Previous studies have shown varying levels of anti-vaccine sentiment on different text-based platforms. The prevalence of anti-vaccine sentiment in our study resembles that of the Facebook research which also only analyzed childhood-vaccine specific content, which can be explained by previous researchers' observations that childhood vaccines evoke more anti-vaccine sentiment among the population in comparison to other vaccines (Powell et al., 2016).

Shared linguistic properties are crucial to identity formation online (Bäck, Bäck, Sendén, & Sikström, 2018) and overtime, becomes "sticky information", not only in terms of information but also the attributes of the participant, often difficult to transfer between groups (Von Hippel, 1994, p.3). Some of the most frequently used words and their correlated sentiment in our study resembled those within the corpus of vaccine-related

tweets in North America (Dredze, Wood-Doughty, Quinn, & Broniatowski, 2017; Kang et al., 2017), suggesting a potential crossover of influence from outside of Canada within separate vaccine sentiments.

With respect to network structure, of particular interest in our findings was the level of high reciprocity, and high centrality of pro-vaccine and anti-vaccine sentiment, which indicates that they are more resilient to random failures (e.g., removal or withdrawal of random nodes), but more vulnerable to targeted attacks such as the removal of high centrality nodes (Albert, Jeong, & Barabási, 2000; Borgatti, Carley, & Krackhardt, 2006; Callaway, Newman, Strogatz, & Watts, 2000; Kim & Anderson, 2013). In a simulation of network dynamics, "relatively few nodes in the network can have a dominant influence over both the quality and quantity of the information shared" (Feng, Hossain, Crawford, & Bossomaier, 2017, p.1). It is thus highly plausible that celebrities and anti-vaccine activists occupying high centrality positions can seriously damage immunization efforts in Ontario. This means that if a node with high betweenness centrality within these profession/affiliation sub-networks becomes anti-vaccine, it is then expected that many surrounding nodes will be exposed to anti-vaccine ideologies, and subsequently create an "infection" in the network. As it turns out, the top 5 broker nodes are all pro-vaccine Twitter accounts that have high visibility, legitimacy, and institutional support within the immunization system. The fact that "people of high status activate larger and less constrained subsections of their networks" (Smith, Menon, & Thompson, 2012, p.76), leads us to expect that pro-vaccine sentiment among brokers will remain stable in Ontario, and is unlikely to be replaced by anti-vaccine sentiment.

Recent studies of large scale social media networks show an average of 4 degrees of separation (Backstrom, Boldi, Rosa, Ugander, & Vigna, 2012). In comparison, our study measured 2 degrees of separation, meaning that my friend's friend is a friend of yours[24]. This could be explained by the following: first, network structures are informed by geographical location (Kleinberg, 2000). Previous research observed that roughly two-fifths of Twitter ties were made within the same metropolitan area, and airline flights were the most significant indictor of long-distance ties, suggesting that geographical distance as well as those whom we already know, were the most significant predictors of who we choose to follow on Twitter (Takhteyev, Gruzd, & Wellman, 2012). This likely reduces the average degrees of separation since Twitter followership can be accounted for by real-life connections. Second, the study collected tweets from Ontario only, yielding a relatively small number, thus the required path length for informational spread is shorter.

The ERGM models from our study suggest that opposing vaccine sentiments reside in distinctive clusters with high intra-reciprocity. Evidence suggests that there is a growing number of anti-vaccine websites compared to pro-vaccine websites, with little crossover in viewership (Ninkov & Vaughan, 2017). Polarizing clusters signify that cross-pollination of information and opinions between clusters are less likely, and those within clusters are affirmed of their beliefs through the "majority illusion" (Lerman et al., 2016) – a phenomenon in which the majority of the population in a cluster falsely assume that what is being broadcast by the few highly central active participant(s) is the general consensus

[24] Not to be interpreted as direct ties, 6 degrees of separation in Milgram's experiment is conceptually 6 intermediaries apart – thus, we are 6 circles of friends apart, or in graph theory jargon, 6 "structures" apart (Backstrom, Boldi, Rosa, Ugander, & Vigna, 2012, p.42). In turn, vaccine conversations on Twitter in Ontario are about 2 structures apart.

towards an issue within the cluster (ibid). This kind of false consensus is concerning because experiments on Twitter showed that a person's likelihood of adopting a new opinion is highly contingent upon the number of adopters in a person's vicinity (Mønsted, Sapieżyński, Ferrara, & Lehmann, 2017).

Strengths and limitations

Our study demonstrated the feasibility of using social media as an efficient and cost-effective data source for capturing vaccine sentiment. The study serves as a stepping stone to future efforts to apply sentiment analysis in the context of understanding public vaccine sentiment online in conjunction with random digit dialing, online surveys, and in-person recruitment, and lack of consent required from participants[25]. This study was successful in identifying that vaccine sentiment and conversations reside in siloes using sentiment analysis and network analysis. The layers of theoretical foundation resting in network theory complements vaccine research to show that geographic location and vaccine sentiment are variables that likely influence the formation of cliques, which may serve as a foundation for the development of strategies to strengthen or weaken the spread of misinformation on Twitter.

Study findings need to be considered in light of two limitations. First, the network created was generated from English tweets only, thus it underrepresents the vaccine sentiment and network structure of those who tweet in other languages. Second, all coding was carried out by a single coder. Despite this limitation, several steps were taken to ensure

[25] As of 2017, Twitter's Terms of Service gives the company the right to share or disclose any user's public profile information, public tweets, followers and those they follow, and all engagements and impressions of a tweet.

the robustness of the coding process including the iterative process used to construct the codebook, with input at key decision points from other members of the research team.

Implications for policy and practice

There are several ways in which our research may be used to inform efforts to address vaccine hesitancy. First, social media presents an opportunity for governments and public health organizations to monitor the content of vaccine misinformation in real-time without surveying the population through traditional surveying methods. This is particularly relevant as the Ministry of Health and Long-Term Care in Ontario restructures its organization to strengthen its capacity for innovation[26] and cross-Ministry collaboration, as well as commitment to investing in information management, data, and analytics. Second, public health agencies and organizations can make use of our results to design strategies that enable collaboration with pro-vaccine broker nodes to bridge sentiment clusters, such as leveraging the structural position of the Minister of Health to initiate pro-vaccine campaigns that bridges structural divides in the vaccine network. In addition, public health communication practitioners should pay special attention to the interactions that occur on social media and to identify anti-vaccine conversations as they occur. The strategic design and decision to respond to popular nodes[27] through the dissemination and spread of ideas can be used to create ties with the public and pro-vaccine network structure.

[26] On June 29th, 2018, the MOHLTC appointed a new positioned called the Chief Health Innovation Strategist, and elevated the Communications and Marketing and Policy and Delivery branch to report directly to the Deputy Minister of MOHLTC (MOHLTC, 2018).

[27] While it might seem counter-intuitive to mention or reply to celebrities such as Jenny McCarthy in a Twitter dialogue or to engage in a conversation with a misinformed individual, our study suggests that it is useful to engage popular Twitter accounts, this may be in the form of hashtags, or mentioning the person, or replying the person, et cetera, to promote the visibility of the tweets.

Implications for future research

This study provides a useful starting point for future research by demonstrating that Twitter is a viable platform for the collection of and measurement of vaccine sentiment and the construction of vaccine-issue networks in Ontario. Future research would greatly benefit from automated approaches that can accurately identify domain-specific sentiment lexicons like SentProp (Hamilton, Clark, Leskovec, & Jurafsky, 2016). Automated approaches as such can detect the dynamic changes of sentiments of a word between communities and monitor changes in meaning overtime, which are particularly useful when analyzing larger datasets of words with different connotations between groups. To offset the diffusion of misinformation, defense strategies such as adding new edges to connect low-centrality nodes to maintain the balance of the network's centrality is one of the potential uses[28] of understanding network structure (Kim & Anderson, 2013).

Using the results of this study, one can design experimental research that examines the structural integrity of vaccine-specific networks on social media. This can be done by simulating node removal, and one can observe whether removing high centrality anti-vaccine nodes or the uniquely anti-vaccine nodes are more effective in terms of slowing down the spread of vaccine sentiment and misinformation. Other research that could complement our study is the use of a harmonic modularity algorithm to identify the "structural holes", or gaps, between clusters to facilitate the exchange and provision of social capital such as ideas and information (Burt, 2004). Depending on the strength of the

[28] For example, a government-affiliated, pro-vaccine Twitter account can create edges by identifying Twitter users in Ontario with very little engagement, and then following these users regardless of their opinions on vaccines.

cluster structure[29], one can then devise strategies to weaken anti-vaccine clusters by altering the sentiment of between-group nodes[30] or by removing brokers and influential nodes[31] (Yang, Li, Chen, Zhang, & Wang, 2015).

Conclusion

A combination of sentiment analysis with social network analysis of the childhood vaccine issue-based network on Twitter provided an overview of the prevalence of anti-vaccine sentiment, the structural properties of the network, the sentiments and attributes that facilitate tie-based connections in the vaccine network, and the accounts that occupy important positions in the network. Leveraging platform-appropriate strategies, such as active monitoring of social media, implementing node-level sentiment strengthening and brokerage, and evoking pro-vaccine sentiment using news and events to bridge pro-vaccine and anti-vaccine clusters, are encouraged. Understanding the structural properties of the vaccine network specific to Ontario enables public health professionals to approach social media with strategies to increase engagement to break out of pro-vaccine sentiment siloes.

[29] Community structures are formed when 'connections between members of a group of nodes are more dense than connections between members of different groups' (Salathé & Jones, 2010, p.1).
[30] Useful for breaking down networks with strong community structures (Yang, Li, Chen, Zhang, & Wang, 2015)
[31] Useful for breaking down networks with weak community structures (ibid).

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Table 1. Network properties of whole network, modularity, account type, and sentiment

	Network Properties					
		Connectivity			Cluster	Centrality
	Nodes (edges)	Diameter	Characteristic path length	Density (%)	Average clustering coefficient	Average weighted degree
1. Whole network						
Whole network	718 (734)	6	2.659	0.1	0.196	1.175
2. Sub-network partitioned by modularity						
Cluster A	249 (314)	5	2.599	0.5	0.062	1.372
Cluster B	170 (156)	4	1.526	0.7	0.086	1.436
3. Sub-network partitioned by profession/affiliation						
Ontario public health units	24 (11)	3	1.438	2.2	0.008	0.5
Public health	20 (1)	1	1	0.3	0	0.05
Health professionals	120 (18)	1	1	0.1	0	0.175
Celebrities	24 (1)	-	-	-	0	0.042
Politicians	64 (0)	0	1	0	0	0
News media	133 (28)	1	1	0.2	0	0.211
Antivaccine	73 (41)	4	1.537	0.8	0.009	1.055
Public	224 (36)	1	1	0.1	0	0.17
4. Sub-network partitioned by sentiment						
Negative	201 (116)	4	1.429	0.3	0.012	0.836
Positive	400 (295)	5	2.624	0.32	0.014	0.787
Neutral	117 (14)	1	1	0.1	0	0.12

Table 2. Structural features and attributes underlying tie formation in the vaccine network on Twitter

		Model 1		Model 2		Model 3		Model 4	
		EST	SE	*EST*	SE	*EST*	*SE*	*EST*	*SE*
Structural features									
Edges		**-4.99**	0.055	**-5.32**	0.07	**-5.99**	0.10	**-5.95**	0.09
Isolates						**-2.09**	0.24	**-3.10**	0.23
Reciprocity		**2.47**	0.40	**2.32**	0.42	**2.98**	0.42	**2.95**	0.46
Centrality		**-2.63**	-0.11	**-2.57**	0.11	**-3.10**	0.11	**-3.08**	0.11
User attributes									
Vaccine sentiment	Positive			**0.50**	0.06	**0.42**	0.10	**0.42**	0.09
	Negative			**0.89**	0.09	**1.08**	0.12	**1.12**	0.12
Region	Canada					**0.51**	0.07	**0.82**	0.09
	Undisclosed					**0.85**	0.20	**0.91**	0.18
Profession/affiliation								**-0.36**	0.09
Akaike Information Criterion (AIC)		10619		10537		10133		10121	
Bayesian Information Criterion (BIC)		10652		10593		10222		10221	
* Coefficients in **bold** are significant, CI=99%, only significant variables were shown in this table.									

Figure 1. Word cloud of the vaccine conversation on Twitter in Ontario, April, 2013-March, 2016 (Dark green: pro-vaccine, red: anti-vaccine, light green: neutral and/or words used by both pro- and anti-vaccine accounts)

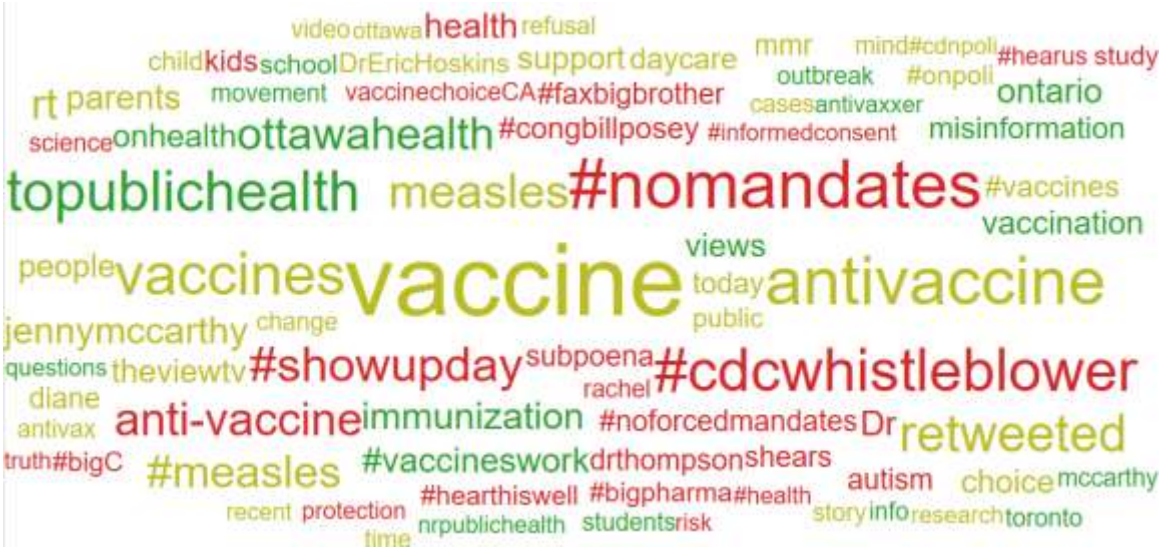
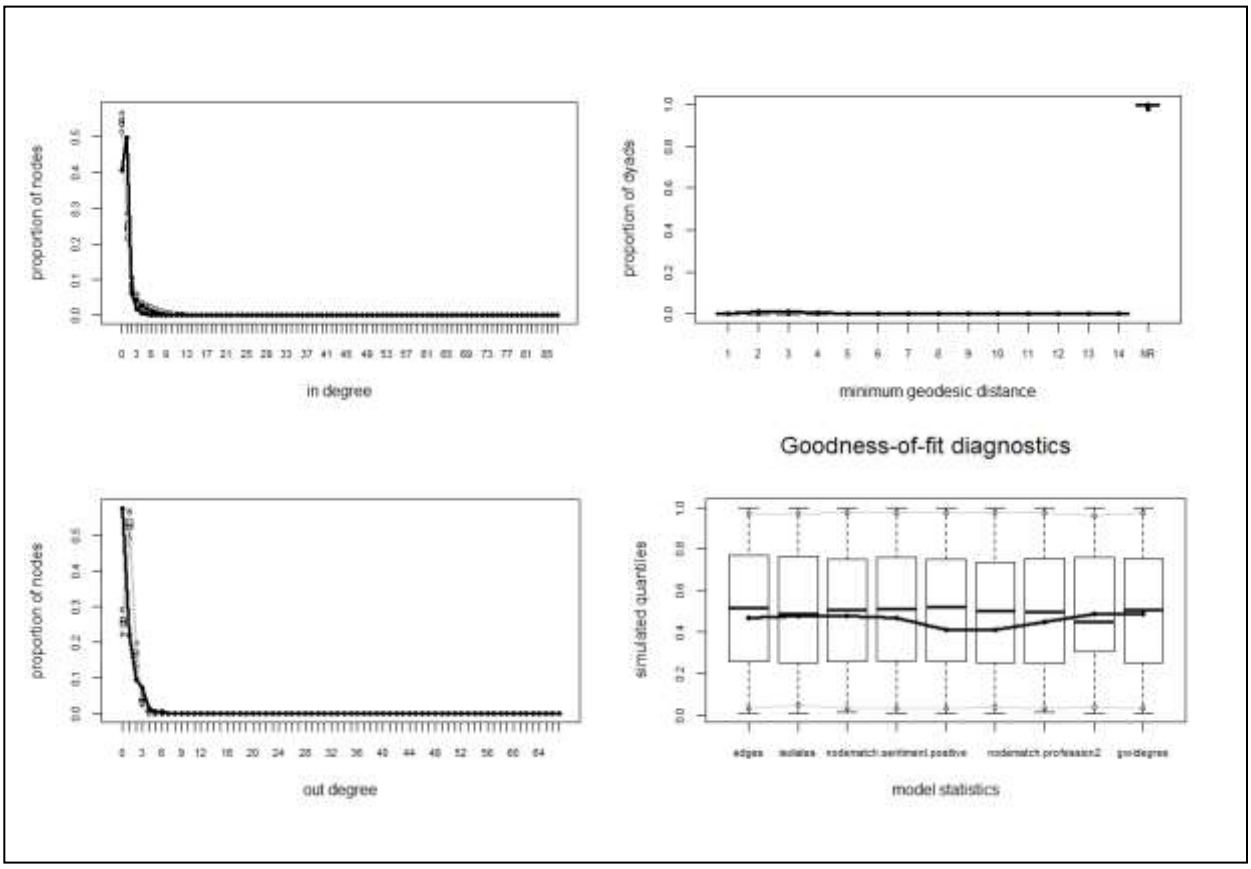


Figure 2. Goodness-of-Fit Diagnostic of Model 4



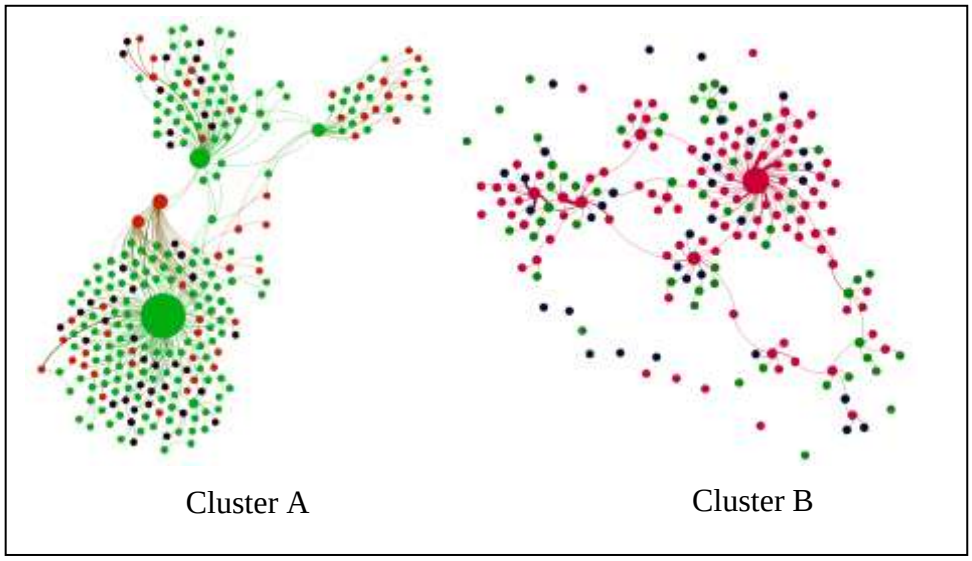
Appendices

Appendix 1. Glossary of network analysis terminology

Terminology	Definition
Nodes/Actors	The most basic element of a network that indicates a person, a point, an account.
Edges/Links/Ties	One of the most basic elements of a network, edges/ties/links are used interchangeably depending on the traditions of a discipline. They are the connections made between nodes. In Twitter, this would mean a meaningful mention, retweet, or reply from one node to another.
Ego-centric network	Patterns of social relations stemming from specific focal points or nodes, it is used to collect network data on phenomena of or affecting the individual, such as a person's Twitter network.
Network diameter	Calculated by measuring the average of shortest path lengths (e.g., number of nodes between two nodes) of two nodes furthest from each other within a network. Ranging from 0 to 1, 1 indicates that every node is connected to every other node, 0 means that no node is connected with any nodes in the network. The closer the diameter is to 1, the larger the network size.
Connectivity	Connectivity is a series of network properties as measured by diameter, characteristic (or average) path length, and density that demonstrates how nodes connected and how information is being diffused in the given network
Average path length	The characteristic path length of a network is to be interpreted along with the diameter, density, and betweenness centrality of the network; it is the shortest average distance between any two nodes in the network (Brandes, 2001).
Network density	Calculated by dividing the number of existing edges by the number of possible edges in existence, the density of a network assesses the speed of the spread of information. The higher the percentage, the more tight-knit is the conversation.
Clusters	Clusters are a group of densely connected nodes that are more likely to communicate with each other than with nodes outside of the cluster (Netlytic.org, 2017)
Clustering coefficient	The measurement of the average completeness of neighborhood of any given node, which is calculated by the mean shortest path to measure the existence of a "small-world" effect (Watts & Strogatz, 1998). In other words, it is the probability that any two nodes connected to node "x", are connected to each other. Ranging from 0 to 1, 1 indicates that every node in the network is connected to every other node.
Modularity	Measured by partitioning the network into interconnected sub-networks to tell apart unified versus divided structures from a range of 0 to 1. The larger the modularity, the more unified the network, it is the reverse value of a clustering coefficient. (Himelboim, Smith, Rainie, Shneiderman, & Espina, 2017).
Degree centrality	A combination of in-degree and out-degree centrality in networks with directionality. Example: Twitter accounts with lots of traffic (e.g., retweeting, being retweeted at, being mentioned, and mentioning others). Nodes with larger degree centrality signifies power/prominence.

In-degree centrality	Used in datasets containing directionality, in-degree centrality is measured based on the number of edges/ties that is directed towards a certain node of inquiry. Example: being Tweeted to, or being mentioned on Twitter. Nodes with larger in-degree centrality signifies popularity.
Out-degree centrality	The opposite of out-degree, it is the measure of the number of edges/ties that is directed from a node of inquiry outwards to other nodes. Example: tweeting at somebody or mentioning or replying to someone on Twitter. Nodes with larger out-degree centrality signifies gregariousness.
Betweenness centrality	Betweenness centrality shows how well a node connects to other nodes. Measured by the number of times a node acts as a bridge along the shortest path between two other nodes, a higher betweenness indicates that a node is more central and connected to others (Freeman, 1978; White & Borgatti, 1994).
Definitions derived from the Encyclopedia of Social Networks, 2011; Netlytic.org, 2017; and the SAGE handbook of social network analysis, 2013.	

Appendix 2. Network clusters based on modularity, colored by sentiment (red indicates anti-vaccine sentiment, green indicates pro-vaccine sentiment, black indicates neutral sentiment)



Appendix 3. Important nodes in the Twitter vaccine conversation in Ontario by centrality measures, 2013-2016.

Roles	Centrality measure	Twitter account ranking	Legend
Influencers	Out-degree and in-degree	1. @TOpublichealth (+) 2. @ottawahealth (+) 3. @ONThealth (+) 4. @JennyMcCarthy (-) 5. @TheviewTV (n)	@TOpublichealth and @ottawahealth are the official accounts of local public health agencies for the City of Toronto and Ottawa, respectively. @ONThealth is the official account of Public Health Ontario. Account 4 is a celebrity in the USA, and @TheviewTV is a talk show in the USA.
Broadcasters	Out-degree	1. @1apizzi630 (-) 2. @TOpublichealth (+) 3. @1eather_fraser0 (-) 4. @1ianeshears0 (-) 5. @1tutzy60 (-)	Besides @TOpublichealth, all other broadcasters are anti-vaccine, including 2 who tweet anti-vaccine content only, and two who are members of the public, among them is @1eather_fraser0 influential blogger that promotes healthy eating for children with peanut allergy.
Popular	In-degree	1. @TOpublichealth (+) 2. @1apizzi630 (+) 3. @ottawahealth (+) 4. @JennyMcCarthy (-) 5. @1eather_fraser0 (-)	Popular accounts are those that people talk to or connect with the most. These accounts are sometimes influencers and broadcasters.
Brokers	Betweenness	1. @TOpublichealth (+) 2. @Ottawahealth (+) 3. @ONThealth (+) 4. @1rflanders0 (+) 5. @Drerichoskins (+)	All brokers in this network are pro-vaccination. The 4th broker is a physician with no affiliation to public health agencies, and the 5th broker is the then-Ministry of Health and Long-Term Care.
The efficiently positioned	Closeness	1. @TOpublichealth (+) 2. @1burke850 (-) 3. @1apizzi630 (-) 4. @snccla (-) 5. @1uzynotes0 (+)	3 anti-vaccine accounts and 2 pro-vaccine accounts occupy this role. Besides @TOpublichealth, the rest are "the general public".
Accounts not affiliated with public health units or public figures are anonymized by replacing letters in the front and end of their account names. The minus sign (-) indicate negative vaccine sentiment, the plus sign (+) indicate positive vaccine sentiment, and (n) indicates neutral sentiment on vaccines.			

Chapter 3. Preface

This thesis chapter draws on the same data source as for the previous chapter but explores a different study question and set of objectives. Whereas the previous chapter examined "conversation clusters by sentiment", the analysis presented in this chapter explores "what's being said and by whom". The study uses an iterative mixed methods content analysis informed by theory from a number of relevant disciplines. Results highlight both the unique communicative patterns of Twitter as a standalone platform as well as its position in an intricate and hyperconnected ecosystem that may divide, converge, evolve, and inform public beliefs towards vaccines, depending on how it is used.

I led the design of the study, as well as the coding, analysis, and interpretation of the data. Julia Abelson provided key contributions to the analytical coding schemes used and the overall structuring of the paper. John Lavis and Anatoliy Gruzd reviewed and commented on several chapter drafts and made suggestions for improving key aspects of the analysis and the overall structuring of the paper.

Chapter 3: Content analysis of childhood immunization-related tweets in Ontario, Canada between 2013 and 2016

Abstract

Introduction: Social media has become a platform for promulgating messages that have contributed to the rise in vaccine hesitancy worldwide, yet little is known about this phenomenon in the Canadian context. **Objectives:** To describe the association between vaccine sentiment and various Twitter user attributes, including affiliation or profession, emotion, embedded or linked medium, direction of sharing, use of Twitter functions; to qualitatively explore vaccine-related medium (text, images, video, multimedia) and content of links shared in tweets; and to identify the underlying reasons for negative vaccine sentiment. **Methods:** Using the Twitter standard search API, tweets about childhood vaccines in Ontario, Canada between 2013-2016 were collected. Using a mixed-methods coding process, coding schemes were established for 6 Twitter user attributes (i.e. profession/affiliation, emotion, embedded or linked medium, direction of information-sharing, use of Twitter functions, and reasons for negative vaccine sentiment). Quantitative content analysis was used to explore differences in these attributes among users expressing different vaccine sentiments (pro, neutral and negative). Qualitative analysis was carried out to analyze the content of shared links, and a thematic analysis was carried out to identify reasons for negative vaccine sentiment. **Results:** Users expressing pro-vaccine sentiment were more likely to affiliate with health-related professions, express positive emotions, share text-heavy links, and retweet and share information with non-specific audiences. Neutral vaccine sentiment users were predominantly news media accounts that shared links

with multimedia news websites. Negative vaccine sentiment users were more likely to express negative emotions, share more images, and call for action. Citing false evidence from pseudo-experts, and pseudo-experts spreading misinformation were the most dominant narratives that sustained the negative vaccine sentiment. **Discussion:** In Ontario, Twitter users who are anti-vaccine exhibit 5 behavioral and users attributes that are different from pro-vaccine users. This study provides preliminary support for the use theories of communicative action and paying attention to differences in the medium of communication, and the affordances of social media which are interconnected with other social media platforms and the internet at large to understand how the vaccine hesitant communicate. **Conclusion:** Users with different vaccine sentiments use Twitter differently, necessitating the design of tailored health promotion strategies.

Introduction

It is widely acknowledged that the internet in general and social media in particular have contributed over the last decade to the increased levels of vaccine hesitancy observed worldwide (Getman et al., 2017; Larson et al., 2014; Majewski & Beger, 2013; Repalust, Šević, Rihtar, & Štulhofer, 2016). While vaccine hesitancy is a global phenomenon, it is highly contextual and varies greatly depending on the sociopolitical, economic, and organizational climate (Larson et al., 2016). For instance, in countries with higher GDP and easier access to vaccines, such as the US, there is a firmly established correlation between areas with higher prevalence of conscientious exemptions to school immunization and the likelihood of vaccine preventable disease outbreaks (Lieu, Ray, Klein, Chung, & Kulldorff, 2015; Tomeny et al., 2017a; Yang, Delamater, et al., 2016). High-income, higher educational attainment, private-school attendance, women who have just given birth, and white ethnicity have been found to be positively correlated with vaccine hesitancy (McNutt et al., 2016; Yang, Delamater, et al., 2016) across the political spectrum (Jamieson, Kahan, & Scheufele, 2017; Kahan, 2014). Qualitative studies have interpreted this phenomenon to have arisen from the false empowerment of belonging to "an imagined gated community" that comes with the privilege of choice (Reich, 2014).

To date, health promotion efforts based on the health belief model and theories of self-efficacy in evaluating behavioral change have had limited success in addressing vaccine hesitancy (Glanz et al., 2017; Odone et al., 2015). Further, few, if any, strategies used in the online environment have been shown to be effective in increasing vaccine confidence and uptake. In contrast, considerable evidence has accumulated which

demonstrates that online environments provide an effective portal for the spread of conflicting vaccine information that can influence individual decision-making processes (Getman et al., 2017; Kata, 2012). More specifically, over half of all websites containing vaccine content have been found to present information opposing vaccines and to use persuasive techniques to promote misinformation in conjunction with alternative treatments that resonate with parents' pursuit of a 'natural' lifestyle (Moran, Everhart, Lucas, Morgan, & Prickett, 2015). Anti-vaccine sentiment has become the dominant sentiment expressed across a range of social media platforms, from roughly 34% on YouTube in 2007 (Keelan, Pavri-Garcia, Tomlinson, & Wilson, 2007), to over 60% in 2017 (Basch et al., 2017; Song & Gruzd, 2017), and as high as 75% on Pinterest in 2017 (Guidry, Carlyle, Messner, & Jin, 2015).

The use of social media among different professions/affiliations in relation to the issue of vaccine hesitancy

How and to what extent public health and health-related government institutions, health professionals, news media, and the public use social media to discuss vaccination in comparison to anti-vaccine users has been under-explored. Although harnessing social media for knowledge translation in the academic setting is well established (Ho & Peter Wall Workshop Participants, 2014), public health and health-related government institutions are subject to rules and regulations that guide social media conduct, where concerns remain, as third-party platforms do not conform to the terms of provincial and federal requirements regarding acceptable use, data use, accessibility, and privacy policies (Bertot et al., 2012; Mergel, 2012, 2014). In a similar vein, many health professionals

refrain from interacting with the public due to concerns about damaging their professional image, breaches to patient privacy, violation of the patient-provider boundary, and licensing and legal issues (Brown, Ryan, & Harris, 2014; Moorhead et al., 2013; Ventola, 2014).

News media operate under different conditions, and are criticized by public health professionals for having skewed public perception of vaccines by presenting both pro-and anti-vaccine views (Clarke, 2008, 2011; Dixon & Clarke, 2013). The media's attempt to provide a balanced view on vaccines may contribute to the false impression that there is room for debate on vaccine safety (Clarke, 2008). Operating under drastically different conditions, these professions/affiliations all contribute to an imbalance in the vaccine information ecosystem on social media, where the majority of vaccine information is shared by the public (Love et al., 2013), and where the prevalence of negative vaccine sentiment varies corresponding to the media narratives of local news (Powell et al., 2016).

The affordances of social media platforms and its use in relation to vaccine hesitancy

While still an understudied area in the public health field, social media platforms and their design may inevitably shape how and where we obtain and communicate information about topics such as vaccine hesitancy. These platforms allow the sharing of information freely without the need for institutional endorsement (e.g., by established health professionals and/or health authorities); without traditional gatekeepers or intermediaries to verify the quality of health information, misinformation and disinformation, the public are vulnerable to the health misinformation and products that celebrities endorse and promote (Caulfield, 2016; McCartney, 2017; Yiannakoulias,

Tooby, & Sturrock, 2017). Empirical evidence shows that photos, faces, and videos, attract more clicks, retweets, and shares on social media (Bakhshi, Shamma, & Gilbert, 2014; Hofmann, Beverungen, Räckers, & Becker, 2013; Redsicker, 2016; Strekalova & Krieger, 2015), and anti-vaccine images with accompanying texts were more readily accepted due to an easier readability compared to pro-vaccine content (Okuhara et al., 2017). Understanding these "affordances of social media platforms" (Bucher & Helmond, 2017) is crucial for informing the design of social media interventions that can shape attitudes and behaviours in areas such as immunization decision making. To the extent that the public's decision-making processes are influenced by the symbols, algorithmic designs, and the types of media through which vaccine information proliferates, a better understanding of the relationship between vaccine sentiment and user attributes is needed.

With growing evidence suggesting that the use of social media for health information seeking has facilitated the proliferation of negative vaccine sentiment in Canada, coupled with the fact that vaccine hesitancy is highly contextual, this study has the following aims: i) to describe the association between vaccine sentiment and various Twitter user attributes, including affiliation or profession, emotion, embedded or linked medium in tweets, direction of information-sharing, and use of Twitter functions; ii) to qualitatively explore vaccine-related medium and links shared in tweets, and iii) to describe the reasons underlying negative vaccine sentiment.

Methods

We carried out a mixed methods content analysis of tweets about childhood vaccines in Ontario, Canada. The study's key methodological details are summarized in Figure 1.

Data sources and collection

Twitter was chosen as the data source for this study due to its popularity among the major social media platforms used in Canada, especially among populations of child-rearing age, due the relatively balanced gender-ratio of users compared to other social media platforms (Statistica, 2017) and due to the relative ease with which data can be obtained in terms of data extraction and data-sharing policies of the social media platform.

Public tweets in Ontario[32] between April of 2013 and March of 2016 were collected using Twitter's standard streaming API. The unit of analysis - a "tweet" - consisted of one or all of the following: words, sentence(s), links (URL), embedded images (e.g., picture, photos, gifs), embedded videos, and Twitter functions that trigger connection with others (e.g., @, #, RT). Two datasets of independently retrieved tweets were created and merged, including: (1) tweets containing all or any of the following keywords - "MMR", "vaccine, "anti-vaccine" and "antivaccine" in Ontario; and (2) all tweets from local public health agencies (i.e., 36 Public Health Units[33]) related to vaccination. Exclusion criteria include:

[32] We originally retrieved geo-tagged tweets that identified themselves as located in the Province of Ontario, and in major Ontario cities (i.e., Toronto, Ottawa, Mississauga, et cetera). However, only 1% or fewer Twitter accounts have set up geotags (Han, Cook, & Baldwin, 2014), we thus established the query to search for tweets within a radius of 150 miles around Toronto.

[33] "A Public Health Unit is the official health agency established by a group of urban and rural municipalities to provide a more efficient community health program, carried out by full-time, specially qualified staff. […] Each unit is governed by a board of health, which is an autonomous corporation under

dengue fever, HPV, flu, and Hepatitis vaccine. Given that social bots are prevalent on Twitter, consisting of anywhere between 9-15% of accounts (Varol, Ferrara, Menczer, & Flammini, 2017), accounts established solely for anti-vaccine purposes might be social bots designed to spread alternative information (Boshmaf, Muslukhov, Beznosov, & Ripeanu, 2013; Nied, Stewart, Spiro, & Starbird, 2017). To verify this, we used "Botometer", open-source software developed by the Observatory on Social Media (OSoMe) of Indiana University to provide a percentage[34] estimate of the authenticity of these Twitter accounts. If accounts exhibit traits of a social bot, the coder resorted to rereading the tweets from these Twitter accounts' and its most recent 20 tweets to determine whether they are bots and need to be excluded from the study.

We adhered to the ethics of social media data collection (Davis, Varol, Ferrara, Flammini, & Menczer, 2016; Eysenbach & Till, 2001; Moreno, Goniu, Moreno, & Diekema, 2013) to ensure that the privacy and confidentiality of public tweets were protected. This study was approved by the Hamilton Integrated Research Ethics Board (HIREB) in November, 2015.

Data coding

We applied three levels of coding to the data. During first-level coding, we took an inductive process to open-code words, sentences, phrases, and hashtags of a tweet. Using a constant comparative method (Glaser & Strauss, 2017), we identified an underlying pattern

the Health Protection and Promotion Act, and is administered by the medical officer of health who reports to the local board of health.". Retrieved from the Ontario Ministry of Health and Long-Term Care website, URL: http://www.health.gov.on.ca/en/common/system/services/phu/

[34] A percentage calculation of more than 50% indicates likely bot-like behaviour (Davis, Varol, Ferrara, Flammini, & Menczer, 2016).

of distinctive behavioural attributes among different sentiments. Interpretive memos were created and revisited between coding. Six attributes identified in first-level coding (i.e., profession/affiliation, overall emotion, medium shared in tweets, direction of information-sharing, use of Twitter function, content in links) contributed to the initial codebook.

During second-level coding (focused coding), a pattern-matching technique was employed to explore the underlying incentive/purpose of the tweet (e.g., inspecting the narrative, the content in the links). At this stage, three groups of theory were drawn from the public relations, communications, and vaccine hesitancy literature, to support and contrast with the patterns identified in first-level coding: i) the theory of affordances of social media platforms, which proposes that platforms and their design influence the types of links shared on the medium; ii) the theory of communicative action, which carries notions that emotions drive, in part, the need to communicate as well as to whom the communication is directed; and iii) theories of the reasons for vaccine refusal, which categorizes themes of global vaccine hesitancy not contextualized in Ontario. In addition to theoretical foundations to the codes, previous researchers' work on vaccine sentiment analysis on social media, and general emotion, and use of Twitter functions were used as priori ensure the coding schemes were empirically grounded and credible, such that 'adequate representation of the constructions of the social world under study' (Bradley, 1993, 436). The definitions and rules of assignment for quantitative categorical coding were simultaneously developed.

Third-level coding was conducted to refine all coding schemes and to inspect for consistency. The final codebook contained 6 coding schemes, including 1 coding scheme

of vaccine sentiment (pro-, neutral, anti-) as an independent variable during data analysis, and coding schemes for 5 dependent variables, including (1) profession/affiliation (4 major profession/affiliation categories and 22 sub-categories[35]), (2) general emotion conveyed in tweets (positive, neutral, negative), (3) embedded or linked medium (None, Text, Image, Video, Multimedia), (4) direction of information-sharing (information sharing, information seeking, call for action), and (5) use of Twitter function (mention, reply, retweet). (See Appendix 1, codebook s1-6). We also identified 2 schemes that required qualitative content analysis, including (1) content in link: all URLs[36] were explored in terms of content, mission/visions, user-interface design, and the use of multimedia, and (2) reasons for negative vaccine sentiment derived from tweets and shared links. For the latter, an initial codebook was constructed as a reference for the thematic coding process (See Appendix 1, codebook s7).

These coding schemes were tested on 100 randomly selected tweets from our dataset. The coding manual was revisited repeatedly to avoid "drifting into an idiosyncratic sense of what the code means" (Schilling, 2006). After multiple iterations, the categories, definitions, and rules for assigning codes was finalized and were used to create structured matrices for quantitative analysis. To avoid single-coder bias, the primary author and one co-author were consulted to ensure confirmability, which is the 'extent to which the characteristics of the data, posited by the researcher, can be confirmed by others who read

[35] After reviewing all 374 Twitter accounts, including browsing their profile pages and reading at least 10 of the most recent tweets on each Twitter account, we observed that a substantial number of accounts were dedicated for purely anti-vaccine purposes, and thus anti-vaccine tweets were separated from 'the general public' and categorized as 'anti-vaccine'.

[36] Tweets with more than one link (n=3) were categorized based on the first link.

or review the research results' (Bradley, 1993, 437) of coding schemes. In addition, the coder revisited the coding scheme and followed the same coding scheme twice after the initial coding, each time one year apart, to check for intra-rater repeatability to ensure the dependability of the schemes (Mackey & Gass, 2015; Nutter Jr, Gleason, Jenco, & Christians, 1993).

Data analysis

Quantitative content analysis

We calculated the measures of association between vaccine sentiment and 5 dependent variables (i.e. profession/affiliation, emotion, medium shared in tweets, direction of information-sharing, use of Twitter functions) with a standard two-tailed chi-square test of independence.

Qualitative thematic analysis

The thematic analysis of two schemes: "content in shared links" and "reasons for negative vaccine sentiment", were accomplished by manual coding in Excel spreadsheets. To ensure the confirmability of findings and that the constructs of each theme were credible (Elo & Kyngäs, 2008), the contents of each theme were compared against one another to understand their relationships, similarities and differences. We paid close attention to how vaccine sentiment was interpreted in the links and embedded media. The themes emerged from observing the connectivity of tweets, links, sentiment, and emotion of the users that were objectively placed in the context of relevant vaccination beliefs documented in vaccine-hesitancy reviews and frameworks. The principal coder iterated between reading tweets, reading the profiles of Twitter accounts, as well as the content of the links shared,

paying close attention to the perceived realities of the Twitter user to interpret the possible reasons for negative vaccine sentiment.

Results

Vaccine sentiment and measures of association with Twitter attributes (Tables 1 and 2)

Of the 374 unique accounts that had ever tweeted about childhood vaccines between 2013-2016, 59% expressed positive sentiment, 13% expressed neutral sentiment, and 28% expressed negative sentiment (Table 1). Four main profession/affiliation categories and 22 sub-categories were identified. The 4 profession/affiliation categories include: "the general public" (56%), e.g., the public, scientists and researchers not belonging to health-related fields, private industries and companies, politicians and celebrities [37], as well as unidentifiable account types; "health-related" (24%), e.g., a combination of healthcare professionals, alternative health (e.g. chiropractor, naturopathic doctor, homeopathic doctor), public health professionals, regional public health units, international/federal/provincial public health organizations, medical associations, pharmaceutical companies, and Local Health Integrated Networks (LHINs); "news" (10%), e.g., accounts of individual journalists, accounts of local news channels and news websites, mainstream news, alternative news stations, talk-shows/podcasts, and bloggers; and the "anti-vaccine" (10%), e.g., accounts that specifically post anti-vaccine tweets or accounts that have posted more than 3 different types of conspiracy theories in the most recent 10

[37] The rationale for including politicians (N=3) and celebrities (N=2) in 'the general public' category, identified by the 'verified Twitter account' blue icon next to their user account, is due to their posts resembling the content of the general public, which is more general and broad, non-health or news specific, and neither do they only post anti-vaccine content.

tweets. Three accounts possessed traits of social bots but were determined to be human-operated[38] upon manual examination and thus remained in the analysis.

As shown in Table 1, a two-tailed chi-square test of independence was conducted to determine whether different profession/affiliation groups express different vaccine sentiments (X^2 (df = 6, N= 374) = 184.98, p = 0.001). The "health-related" profession/affiliation group was more likely to be pro-vaccine (n=89), and 'news' accounts were significantly more neutral compared to other profession/affiliations. Half neither endorsed nor opposed vaccines and tweet contents intended to prompt discussion and link click (N=21).

Significant relationships between vaccines and overall emotion were also observed (X^2 (df = 4, N = 748) = 25.90, p < 0.001) (Table 2). Tweets in favour of vaccines conveyed more positive emotions, whereas anti-vaccine tweets were slightly more likely to express negative emotions. For instance, in response to Toronto Public Health's vaccine advertisement, one user replied, *"@TOPublicHealth So parents who decide against the vaccine are bad parents who refuse to protect their children? I hate this ad*." The majority of tweets were emotionally neutral (e.g., attentive, assertive, inquisitive), and mostly assertive in their position towards vaccines. For instance, *"@NRPublicHealth cod liver oil & vitamin C reduces mortality and severity of measles symptoms, vaccine is ineffective"*

[38] Real Twitter accounts usually contain the following characteristics: disclosure of location (e.g., geotagged or disclosed through other means), has non-bot friends, and their tweets contain a wider array of sentiment and lesser noun use (Varol, Ferrara, Davis, Menczer, & Flammini, 2017).

expressed anti-vaccine sentiment but not negative emotions (e.g., fear, anger, sadness) or positive emotions (joviality, pride, excitement).

Significant differences in link medium were observed among different vaccine sentiments, X^2 (df = 8, N = 748) = 40.87, p = 0.001). About 59%[39] of tweets contained links (n=441). Users with negative vaccine sentiment shared slightly fewer links and were more likely to embed or share images and video-based content with short and provocative captions or titles. In comparison, users with neutral vaccine sentiment were more likely to share links containing multimedia, which can be explained by the fact that they were mostly shared by news media. Text-based links were most likely shared by pro-vaccine users, such as public health units in Ontario tweeting about vaccine schedules and information on where to receive vaccines. We found only educational video and 1 infographic about immunization produced by the government[40]. With respect to the direction of information-sharing, most tweets shared information (58%), a quarter did not have any information exchange (25%), some "called for action" (11%), and 5% were information-seeking. Pro-vaccine tweets were predominantly information-sharing and were less likely to seek information compared to those with neutral vaccine sentiment. Users with negative vaccine sentiment were more likely to distribute "call for action" tweets (X^2 (df = 6, N = 748) = 111.412, p = 0.001). The use of Twitter function differs among tweets of different vaccine sentiment (X^2 (df = 6, N = 748) = 31.44, p = 0.001). Tweets with negative vaccine sentiment

[39] This represents the number of tweets with links (243 + 45 + 60 + 93 = 441) divided by 748 (all tweets). 441/748 * 100= 59%.

[40] The two videos were produced by Global Affairs Canada, and another by the Ministry of Long-Term Care, featuring children answering the question "Are vaccines safe?". The latter video was embedded in the Government of Ontario website (Ontario.ca) with no social media share-function plug-ins and was only retweeted once.

were more likely to mention and reply to others, tweets with neutral vaccine sentiment were less likely to retweet, mention, or reply to others, and tweets with positive vaccine sentiment were more likely to retweet. In contrast, tweets with negative vaccine sentiment replied to and mentioned others more, both crucial functions for connecting with others as well as "calling for action".

Content in shared links about vaccines (Table 3)

There were 386 unique links, excluding duplicates and expired links, that were shared in the Twitter conversation. The results are reported in the order of positive, neutral, and negative vaccine sentiment.

Anti-vaccine users shared alternative news sites that are labeled as independent, cause-oriented, value-driven sites that expose censored information/news. Anti-vaccine media were usually edited or borrowed without referencing the original source. Anti-vaccine information also featured images with captions or texts quoting politicians, celebrities, pseudo-scientists and alternative health professionals who are against vaccines, such as the Association of American Physicians and Surgeons[41] (AAPS). In particular, the pseudo-scientists and health professionals who were cited, referenced or self-promoted espouse "pretended or spurious science; a collection of related beliefs about the world mistakenly regarded as being based on scientific method or as having the status that scientific truths now have" (Oxford English Dictionary, 1989; cited in the Stanford

[41] The Association of American Physicians and Surgeons (AAPS), founded by licensed medical doctors, promotes vaccine-autism research and claims that infectious diseases are brought into North America by immigrants, et cetera. While its views are not accepted by other medical associations, the AAPS is shared and endorsed by many of the alternative websites, anti-vaccine non-profit blogs, and fake medical experts that we have analyzed in this study.

Encyclopedia of Philosophy, 2018). These individuals usually have personal websites, where they display their titles (e.g., MS, MD, PhD) and describe themselves as helping others avoid "unnecessary treatment". It is more difficult to determine the validity of their credentials (e.g., titles, education) as little information is usually provided except for their social internet presence on YouTube, Facebook, Twitter, et cetera. High-traffic anti-vaccine websites[42] capitalizing on the "search for truth" contain hyperlinks that reference the Centers for Disease Control (CDC) in the US, but instead link to fake experts that falsely interpret vaccine research. These websites contain "clickbait" articles linking to fringe science, often accompanied by haunting images and stories of "vaccine damage"; they invite guest bloggers to share tips on how to identify "vaccine injury" and spread false news on vaccination; a handful of them share imagery and video-heavy fake news sites like World Net Daily and Red Ice[43] with dramatic headlines promoting anti-vaccine agendas. A total of 26 grassroots initiatives were identified, encouraging civil engagement to oppose mandatory vaccination (e.g., by signing petitions, attending rallies, informing others, et cetera), and displaying links to alternative health news sites and non-profit organizations that promote liberalism, healthy-living, anti-establishment, and/or anti-globalization[44], with some sites claiming to participate in the global movement of fighting against vaccination[45]. We observed 2 Canadian anti-vaccine websites (i.e., the Penta Project and Vaccine Choice Canada) that are parent-led and well connected with US anti-vaccine websites. Overall, anti-vaccine websites were easier to navigate than government websites

[42] Examples include, NaturalNews.com, VaccineImpact.com, VacTruth.com
[43] Red Ice uses "Dispelling the mythmakers" as their slogan (https://redice.tv).
[44] Examples include Sumofus.org, Followthemoney.org, Organiclifestyle.com.
[45] Examples include FiercePharma.com, LibertyCampaign.org, RescuePost.com, and LearnTheRisk.org.

promoting vaccines. Their language is easier to understand, and they have a smooth user interface with options for social media sharing.

Pro-vaccine links include all government-sponsored websites (N=79), these links are mostly regional and provincial websites containing local immunization schedules tweeted by the organization themselves, retweeted among each other, or referenced by local news websites. Toronto Public Health (TPH)[46] was the most referenced link in Ontario between 2013-2016. It was also the only public health unit, or any health-related institutions that had made any statements directly against the anti-vaccine movement[47]. The popularity of both Jenny McCarthy and The View[48] has resulted in TPH's tweet being widely shared by major Canadian news channels such as The Globe and Mail, The Star, Huffington Post Canada, Global News. We also identified links shared by health professionals containing journal articles and scientific reports (N=12), Pro-vaccine users share websites that disseminate health sciences research. The content shared is easier to read than government-sponsored websites, contains correct links to journal articles, and encompasses a wide range of health information. Science-focused blogs are another popular form the website pro-vaccine users share. Among them is sciencebasedmedicine.org – the most referenced

[46] Toronto Public Health's official website is the most frequently linked in this category: they actively engage in two-way communication, such as holding Twitter Q&A sessions with the local Medical Officer of Health on immunization, measles, vaccination schedule, and responding to the public's questions. They tweet and retweet the same content intermittently to increase the visibility of its link across social media platforms; and the content they produce are retweeted by other public health units.

[47] Toronto Public Health tweeted directly at Jenny McCarthy and The View to reconsider the decision to hire US anti-vaccine celebrity Jenny McCarthy to host the show and attached a URL of its own measles immunization page. The tweet read, "@JennyMcCarthy anti-vaccine views = misinformation. Please ask @theviewtv to change their mind http://ow.ly/nca3Y".

[48] In 2016, The View was available to all CTV subscribers in Canada. It had an average of 2.7 million viewers, and 550,000 women between the ages of 25-54 ("'The View' sees ratings lift in election season," 2016) in the US alone. Canadian data unavailable at the time of writing.

website by the pro-vaccine general public as well as healthcare professionals. Vaccine-related news typically includes a stock photo of a needle, an arm, a crying baby, and/or health professionals administering vaccines or a combination of the above.

Reasons for negative vaccine sentiment in Ontario (Table 4)

The five main reasons identified for negative vaccine sentiment are alternative evidence, adverse events, mistrust, alternative treatment, and other concerns. Links and hashtags shared by users with negative vaccine sentiment contain various examples of *alternative evidence* from scientific or medical experts (N=77), such as false evidence/information/news from pseudo-experts and false evidence promulgated by pseudo-experts themselves. A total of 18 anti-vaccine experts were referenced, almost all of them claiming to hold medical degrees and/or doctorates in a STEM field. Among them is the frequent mention of William Thompson[49], a rumoured scientist from the Centers for Disease Control, known as the "CDC whistleblower". Various examples of *adverse events* including news, blog posts, hashtags included claims about 'vaccine damage', 'vaccine injury', or 'vaccine overload' and shared beliefs that vaccines cause various disease and conditions (e.g., diabetes, brain cancer, organ failure, autism, infertility, neurological disorders). *Mistrust in government* was identified in tweets describing vaccines as part of a conspiracy theory[50], a form of government totalitarianism, pharmaceutical agenda, or the

[49]In a documentary style anti-vaccine video "Vaxxed: From Cover Up to Catastrophe" (FocusforHealth.org, 2015), a person who claimed to be William Thompson telephoned prolific anti-vaccine activists to disclose 'secret documents' exposing the link between autism and measles vaccine, the person's identity is unconfirmed and the voice is unverified.

[50] Conspiracy theories differ from "alternative evidence", the former include speculations derived from mistrust in institutions woven into the fabric of their core beliefs, in a way that nothing the government says should be trusted. The latter focuses on the reference of evidence from pseudo-experts who claims alternative evidence.

naïve assumption that the government is uninformed although the specific institutions responsible for vaccines or immunization policy were rarely if ever described in the links and hashtags. An abundance of information about *alternative treatment* was shared (e.g., holistic medicine, naturopathy, homeopathy, and the promotion of 'green vaccines' to increase childhood immunity). and a small portion of tweets cast doubts on the safety and efficacy of vaccines in the form of information-seeking.

Discussion

Principal findings

In Ontario, vaccine sentiment is predominantly positive, and a quarter of all vaccine conversation contributors have a health-related profession/affiliation, including health-related government institutions and public health agencies, showing that health-related professionals/organizations use Twitter to promote pro-vaccination messages. There were observable differences in Twitter attributes among users with different vaccine sentiment. Tweets with positive vaccine sentiment used more text-based links, and more retweets of news and government information. Neutral sentiment tweets are the least prevalent, and mainly consisted of news articles and multimedia links. Negative sentiment users show more negative emotions and tend to share more image and video-based links, alternative news sources with misinformation, and "call for action" tweets. The main reasons for negative vaccine sentiment include alternative evidence, adverse events, mistrust, alternative treatment, and other concerns related to efficacy. Users share news links the most, although the types of news and sources vary depending on the users' vaccination sentiment. Overall, pro-vaccine users share mainstream or local news media that supports

immunization; while alternative news sources and alternative health news were exclusively tweeted by those who are anti-vaccine. News with a 'balanced' view of vaccines was tweeted the most by everyone, including people who want to seek information on Twitter.

Discussion of qualitative findings

Considerable media hybridity[51] was observed in our dataset: first, over half of the tweets contained links to external websites. Anti-vaccine ideology is not confined to one place nor is it promoted by one person – anti-vaccine websites often hyperlink to other anti-vaccine videos, blogs, and non-profit websites, thus creating the illusion that there is more to "research" and that collective voices against vaccines exist. Research shows that often the public cannot recall where they first read or heard about an event or information but state that they have heard it from 'everywhere' (Stohl & Ganesh, 2014; Tufekci & Wilson, 2012). This 'everywhere-ness' is pronounced on social media where strong cascades of information diffusion are likely to demote the importance of organizational structure and/or promoted communication such as public service announcements or paid advertisements (Bennett, 2012). More worrisome, network research has shown that when 25% of the people adopt a behaviour, it is likely to create a "tipping point" where the rest in the network follows suit (Centola, Becker, Brackbill, & Baronchelli, 2018).

Second, negative sentiment users' "call for action" for the public to attend rallies and sign petitions on anti-vaccine non-profit websites – the promotion of misinformation, conspiracy theories, and alternative treatment options by "grassroots" non-profits are

[51] Media hybridity describes that rapid evolution of communication technologies enable those who understand the power of ubiquitous information diffusion through multiple channels to reshape media and politics, and sometimes even agitate and disintegrate institutional power (Chadwick, 2017).

concerning due to the alignment of narratives with the public's need for an organic, natural, and clean lifestyle. Compounded by the 5 dominant reasons for negative vaccine sentiment, it is a dangerous concoction that may entice hesitant individuals who identify with the "clean lifestyle" narrative in an age of diminished trust in government and commercial sectors (Edelman.com, 2018).

In our findings, 1 out of 10 Twitter accounts[52] detected in Ontario were established exclusively to communicate anti-vaccine information. Although we ruled out the possibility that these accounts were social bots, the increasing sophistication and variety of bots are make them increasingly challenging to identify. In addition, botnets[53] may direct traffic to anti-vaccine incentives, account may also be created by "astroturfers", which are people who create multiple accounts to make an issue seems as if it has originated from different people and different areas (Harris et al., 2014). Both practices increase the likelihood of Twitter users getting exposed to anti-vaccine content as well as the illusion that anti-vaccine is not a minority discourse (Lerman et al., 2016).

The plethora of anti-vaccine content in our study is concerning in two ways: first, despite previous studies suggesting that factual scientific news and conspiratorial news are equally salient, when percolations of either are spread in polarized and homogeneous communities, conspiracies tend to have a longer salience than science news (Del Vicario et

[52] 38 out of 374 accounts.

[53] One area of contention when discussing Twitter's influence and tweeting behaviour is the focus on botnets, which are autogenerated Twitter accounts established to generate traffic and attention for specific incentives. Twitter bots can be used to "reply" and "retweet" almost instantly after a tweet is made. In early 2017, Twitter's developers rewrote its algorithm in an attempt to promote real Twitter accounts, however, as bots grow in sophistication, weeding out bots will be challenging (Oremus, 2017)

al., 2016). Second, pro-vaccine blogs have very little visitor traffic compared to anti-vaccine sites such as Natural News[54], which often gets cross-linked by anti-vaccine blogs and alternative news sites to feature contents by and from pseudo-experts. The above indicate the possibility that anti-vaccine content is here to stay and possibly flourish.

Findings in comparison to other research

The major finding of our study, that attributes differ significantly between vaccine sentiments, represents a novel contribution to the field of vaccine hesitancy research. First, our finding that pro-vaccine users convey positive emotions more often contradicts a previous finding that pro-vaccine users were more likely to be anxious and express concerns about vaccine hesitancy (Furini & Menegoni, 2018). Second, our finding that anti-vaccine accounts share more images and videos compared to pro-vaccine accounts who share more text-based material adds empirical evidence to the use of multimedia for effective public health messaging. For instance, multi-media content shared by US federal health agencies generated significantly more discussion and were associated with more positive sentiment (Bhattacharya, Srinivasan, & Polgreen, 2017), and health promotion campaigns using shock-value and humour were shared more on social media (Gough, Hunter, Ajao, Jurek, McKeown, Hong, Barrett, Ferguson, McElwee, McCarthy, et al., 2017). Third, this is the first quantitative study to show that anti-vaccine accounts reply to, and mention, others more (or use Twitter functions differently than do pro- and neutral

[54] Natural News is a "conspiracy-minded alternative medicine website" (Blake, 2014) and one of the "Top 10 worst anti-science websites" (Dunning, 2011). Currently linked by 24,480 sites, NaturalNews is estimated to have received 7 million readers per month, mostly from North America, the UK, and Australia and New Zealand (Alexa.com, 2017).

vaccine users), filling a gap in empirical research showing that users with negative vaccine sentiment do not seek information but share information, combined with their use of Twitter function in which they call for action. It adds to the vaccine hesitancy literature the finding that anti-vaccine users use social media as a means to organize for action.

The thematic findings for the reasons of negative vaccine sentiment complements previous survey results showing that mistrust (Dubé et al., 2018), adverse events, and concerns on safety and efficacy (Tustin, 2016; Tustin et al., 2017) are main reasons for vaccine hesitancy in Canada. Similar to concerns regarding the high prevalence of practitioners in complementary alternative treatment (CAM) against immunization (Caulfield, Marcon, & Murdoch, 2017), and alternative treatments offered as an 'illusion of choice" for the vaccine hesitant (Reich, 2014), our study show that pseudo-experts with PhDs or MDs are the main source of reference for false evidence, who are furthermore often portrayed as truth-telling, brave, and fearless. Although we identified one popular blog among both pro- and anti-vaccine supporters which has frequently debunked vaccine pseudo-experts[55], it is referenced by the anti-vaccine to attack pro-vaccine beliefs and to further entrench anti-vaccine beliefs (e.g., 'expose' the 'vaccine lies' of the science blogs). This finding complements observations that fact-checking is losing influence in the online media landscape where fake news is thriving and becoming part of the agenda-setting process, influencing the contents of partisan news in the mainstream media (Nyhan et al., 2014; Vargo, Guo, & Amazeen, 2017).

[55] Sciencebasedmedicine.org, findings in our study.

Strengths and Limitations

This study has the following strengths. First, our methodological decision to combine two specific sets of queries (i.e., a query of MMR and childhood vaccine-related by keywords and a query including all childhood vaccine-related tweets from 36 local public health agencies by account and keyword) to identify tweets allowed us to capture a wider spectrum of tweets from both the public and local public health agencies which might have otherwise been overlooked. Second, we recognize that people have different tweeting behaviours and while some tweet frequently, others might be lurkers. We reduced the likelihood of representation bias of vaccine sentiments by analyzing vaccine sentiment by Twitter accounts instead of by tweets. Third, a novel mixed methods content analysis was used and the determination of trustworthiness was achieved by ensuring the dependability of the coding schemes and confirmability of the findings (Schwandt, Lincoln, & Guba, 2007; Yan & Wildemuth, 2016). By separating the general public from the "anti-vaccine" group, which only posts anti-vaccine agendas, and the 'health-related' group, which is predominantly pro-vaccine, has allowed us to understand the true sentiment of the public. However, it is plausible that anyone with vested pro-vaccine or anti-vaccine interests could establish anti-vaccine or pro-vaccine accounts besides their personal Twitter accounts, therefore one should also take into account the limitations of this categorization.

Our findings need to be considered in light of two key limitations. First, this study used one social media platform to collect data, the study findings are not to be generalized to other social media platforms with different demographic and platform affordances. A second limitation was that it was not possible to measure the association of

sociodemographic variables such as gender, income, educational level, and ethnicity with vaccine sentiment not only because almost half of all Twitter accounts in this dataset are operated by institutions, such as news media, or public health units, but also that half of the sample have incomplete sociodemographic variables to be able run an analysis. More studies are required to explore the demographic representations on different social media platforms to tailor health promotion efforts to desired public health outcomes such as increased vaccine awareness.

Implications for policy and practice

The affordances of social media have provided opportunities and challenges for immunization promotion, demonstrated by the popularity of anti-vaccine discourse on Twitter in Ontario. There is a need to encourage experimentation with communicative designs and to allocate resources for public health professionals to apply the evidence about effective communications techniques to the context of immunization in Ontario and within their localized settings. Researchers have cautioned that anti-vaccine sentiment is prevalent among regulated health professionals in CAM (Caulfield, Marcon, & Murdoch, 2017), as such, policymakers should pay attention to the finding that Ontarians have been predominantly sharing information by pseudo-experts, whose strategies exemplify efficient communication methods tailored to different social media platforms, and where lessons can be drawn to design more effective public health campaigns for the public sector (Huesch, Galstyan, Ong, & Doctor, 2016). More strategies that facilitate engagement and information diffusion include mobilizing pro-vaccine publics to become “advertisers” (Laestadius & Wahl, 2017), identifying and appointing trusted institutions to work with

creative advertising agencies to address the concerns of the vaccine hesitant on social media with engaging content (Kanter & Fine, 2010) (e.g., 'Who is William Thompson, did he really work for the CDC?'), and above all, develop and outline the purposes, key performance indicators of implementation, and evaluation metrics for health promotion on social media (Neiger et al., 2012), while at the same time paying attention to inequalities of access to information and health services (Korda & Itani, 2013; Ramanadhan, Mendez, Rao, & Viswanath, 2013; Syred, Naidoo, Woodhall, & Baraitser, 2014).

Interventions such as applying artificial intelligence and deep-learning to generate automatic real-time engagement with users with negative vaccine sentiment and particular user attributes may be worth exploring. Social media continues to provide large amounts of user-generated information that can be used to predict our offline behaviour and preferences. It offers us a shift from "data-scarce to data-rich studies of societies; from static snapshots to dynamic unfoldings; from coarse aggregations to high resolutions; from relatively simple models to more complex, sophisticated simulations" (Kitchin, 2014, p.7). This study amplifies the need to move towards understanding vaccine hesitancy beyond the human factor, such as exploring the implications of using artificial intelligence to mimic human interaction through deep-learning – as evident in the invention and prevalence of Twitter bots in spreading false information observed across all social media platforms - our preferences and behaviour will likely, in turn, be challenged and altered.

Implications for future research

Future research will require a multi-and interdisciplinary approach to facilitate the design and evaluation of evidence-based interventions for the promotion of immunization

materials online and on social media in ways that are sensitive to the link between vaccine sentiment and user attributes. For instance, having had a preliminary understanding of why Ontarians harbour negative vaccine sentiment, one can then adopt novel methods such as Pathfinder Network Scaling (PFnets), a structural modelling technique to extract structural distances between concepts in a conversation network to detect misalignment between the public's vaccine knowledge and that of health professionals (Amith et al., 2017). Second, having learned that anti-vaccine content and pro-vaccine content are shared using different media, it would be helpful to conduct randomized controlled trials to disseminate multiple interventions to fill the public gaps in vaccine knowledge on social media, and monitor information reach (e.g., number of retweets and likes, measures of virality), salience (e.g., calculating the 'duration' of a piece of information being shared), spread (e.g., how much has this tweet been linked elsewhere outside of the platform of dissemination), and levels of homophily (e.g., documentation of the ratio of visits from anti-vaccine and pro-vaccine users). New developments in network modelling have shown to be useful in the early detection of trends (e.g., memes, campaigns, trending news) (Varol, Ferrara, Menczer, et al., 2017) – these models can potentially be applied to identify and alert public health professionals when vaccine misinformation is trending. While this study confirmed that all tweets in our dataset were contributed by humans, it does not rule out that bots contribute to the vaccine conversation on Twitter. Future research should strive to explicate the semantic properties, the frequency of posts, as well as the types of information being posted to differentiate human-curated anti-vaccine accounts from bots and astroturfers, the latter of which employ campaign strategies on social media disguised as grassroots initiatives.

Conclusion

Users with different vaccine sentiment use Twitter differently. The design of health promotion strategies to address the concerns and needs of vaccine hesitant publics is needed, especially when alternative evidence promoted by pseudo-experts is a widely used strategy to promote negative vaccine sentiment. Creating multi-media evidence-based strategies to address vaccine-hesitant concerns, developing material that employs the language of the vaccine-hesitant, and the use of platforms such as Twitter to allow the public to engage with immunization experts are some potential strategies for using social media to improve immunization campaigns in Ontario.

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Figure 1. Framework for mixed methods content analysis

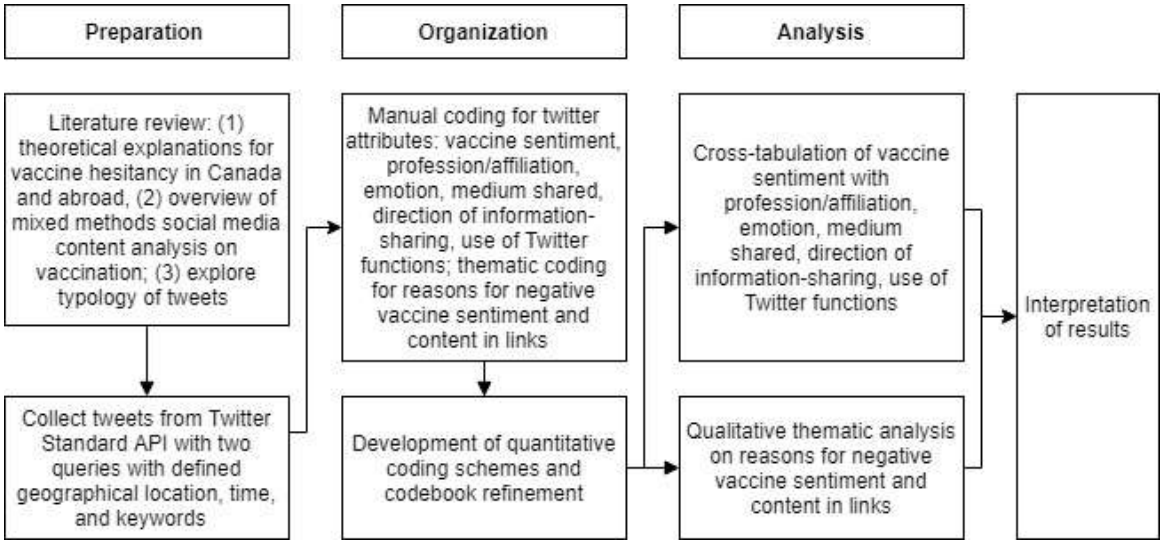

Table 1. Cross tabulation of vaccine sentiment and profession/affiliation category

Vaccine sentiment		Profession/affiliation categories				
		Public	Health-related	News	Anti-vaccine	Total
Positive	Count	122	81	18	0	222
	%	55.0	36.5	8.6	0	100
	Adjusted residual [a]	-2.1	**28.2**	-4.7	-21.4	
Neutral	Count	24	2	21	0	46
	%	52.2	4.3	43.5	0	100
	Adjusted residual	-1.7	-8.9	**15.1**	-4.4	
Negative	Count	63	6	1	36	106
	%	59.4	5.7	0.9	34	100
	Adjusted residual	3.8	**-19.2**	**-10.3**	**25.8**	
Total	Count	209	89	40	36	374
	%	55.9	23.8	10.7	9.6	100

Chi-square 184.98**, p<0.001. The minimum expected count in this table is 4.43, with 2 cells (16.7%) with expected count of less than 5.

[a] Two-tailed chi-square shows that there are marked differences in vaccine sentiment among different affiliations, adjusted residual shows where and what group has an over-representation or under-representation of pro-, anti-, and neutral sentiment, compared to that of a randomly distributed pattern.

Table 2. Cross tabulations of vaccine sentiment by emotion, medium shared in tweets, direction of information sharing, and use of Twitter functions

Vaccine sentiment		General emotionality			Medium shared in tweets					Direction of Information-sharing				Twitter function				
		Neutral	Negative	Positive	No links	Text	Multimedia	Video	Image	Information-sharing	None	Call for action	Information-seeking	None	Mention	Retweet	Reply	Total
Positive	Count	297	47	48	155	144	39	29	25	256	106	19	11	152	123	84	33	392
	%	75.8	12.0	12.2	6.4	36.7	9.9	7.4	6.4	65.3	27.0	4.8	2.8	38.8	31.4	21.4	8.4	100
	Adjusted residual	**-18.5**	1.4	**17.1**	1.4	**16.7**	**-9.7**	-2.4	1.4	28.0	6.4	-25	-9.4	2.6	**-7.0**	**8.0**	-3.7	
Neutral	Count	89	6	2	40	22	29	5	1	59	18	2	18	57	27	9	4	97
	%	91.8	6.2	2.1	41.2	22.7	29.0	5.2	1	60.8	18.6	2.1	18.6	58.8	27.8	9.3	4.1	100
	Adjusted residual	**10.9**	-5.3	-5.7	0.2	-9.5	**16.9**	-2.8	-4.8	2.6	-6.6	-8.9	**12.9**	**20.0**	-5.2	**-9.8**	-5.1	
Negative	Count	216	34	9	112	77	25	26	19	120	66	63	10	76	98	52	33	259
	%	83.4	13.1	20.4	43.2	29.7	9.7	10.0	7.3	46.3	25.5	24.3	3.9	29.3	37.8	20.1	12.7	100
	Adjusted residual	7.6	3.9	**-11.4**	**5.7**	-7.1	-7.2	**5.2**	**3.4**	**-30.6**	0.2	**33.9**	-3.5	**-22.7**	**12.1**	1.8	**8.8**	
Total	Count	602	87	59	307	243	93	60	45	435	190	84	39	285	248	145	70	748
	%	80.5	11.6	7.9	41	32.5	12.4	8.0	6.0	58.2	25.4	11.2	5.2	38.1	33.2	19.4	9.4	100
**p<0.001		Chi-square 25.90**			Chi-square 40.86**					Chi-square 111.412**				Chi-square 31.44**				

Table 3. Links shared in tweets

Vaccine sentiment	Type of links	Sub-type	Websites
Positive	News	Mainstream news	CBC, Globe and Mail, New York Times, Independent, Washington Post, The Atlantic
		Local news	Niagara this week, Toronto Life, Ottawacitizen, CTVnews, Toronto Star, The Age, PhillyVoice, KQED, TOplacenow.com, News9
		Health and Science news	Medical News Today, Med Page Today, Science News, Science Daily
	Non-profit, for-profit, personal blogs	Science blogs	Sciblogs.co.nz, scienceblogs.com, sciencebasedmedicine.org, scienceblog.com
		Commercial	College Humor, Pfizer.com
		Forums	YummyMummyClub.ca
		Magazines	MacLeans.com, Wired.com
	Government sponsored websites	Regional	Niagara Region Public Health, Toronto Public Health, Region of Waterloo Public Health and Emergency, Hamilton Public Health Services, Ottawa Public Health, Eastern Ontario Health Unit, Peterborough Public Health, Porcupine Health Unit, Simcoe Muskoka Public Health
		Provincial	Ministry of Health and Long-Term Care, Government of Ontario, Public Health Ontario
		Federal	Health Canada, Immunize.ca, Global Affairs Canada, Canadian Healthcare Immunization Network, Canada Infoway
		US	Federal Drug Administration, Centers for Disease Control
		International	World Health Organization
	Research and reports	Journal articles	Journal of American Medical Association, Vaccine, Clinical Cancer Research, British Medical Journal
		Health Associations	Canadian Public Health Association (CPHA)
		Hospital	Sick Kids Children's Hospital
Mostly positive	Social Media	Restricted access by default	LinkedIn
Neutral	News	Mainstream news	USA Today, Wall Street Journal, ABC, Yahoo, Huffington Post
	Non-profit, for-profit, personal blogs	Commercial	GreenMedInfo.com, College Humor, Pfizer.com, Mercola.com, Lego.com, Organic Lifestyle.com
Negative	News	Alternative and aggregate news	VaccineImpact.com, Inquisitr.com, Visionlaunch.com, Truthinmedia.com, HealthImpactNews.com, CollectiveEvolution, ActivistPost.com, the Sleuth Journal, VacTruth.com, RedIce.TV, TheLoop.ca, WND.com, NaturalNews.com
	Non-profit, for-profit, personal blogs	Non-profit	Policyoptions.org, avoicefortruth.org, vaccinenation.org, greatergoodmovie.org, fiercepharma.com, globalresearch.ca, libertycampaign.org, rescuepost.com, pentaproject.net, vaccinechoice.ca, followthemoney.org, SumofUs.org, Learntherisk.org

		Commercial	GreenMedInfo.com, Mercola.com, Organic Lifestyle.com
		Personal blogs	Heather Fraser.com, The Nib.com, MP webpages, injury lawyer personal webpage
	Research and reports	Alternative health association	Association of American Physicians and Surgeons (AAPS)
	Social Media	Video-sharing	YouTube, Vid.me, Video214.com, Vimeo.com, VideoYen
Mostly negative	Social Media	Video-sharing	YouTube, Vid.me, Video214.com, Vimeo.com, VideoYen
		No restriction by default	Twitter, Instagram, Tumblr
		Restricted access by default	Facebook
The categories of sources of links is partly informed by Chew and Eysenbach's Twitter analysis of the public's view on the H1N1 influenza vaccine (Chew & Eysenbach, 2010), which best reflects the types of links that would be shared in the context of vaccine information.			

Table 4. Reasons for negative vaccine sentiment in Ontario's Twitter conversation

Category	Number of references	Sub-category	Content mentioned
Alternative evidence	77	Fake experts	"MIT doctor" Stephanie Senneff, Reporter Ben Swann, Dr. William Thompson, Dr, Mark Geir, M.D.,PhD (former NIH researcher, geneticist, previously a professor at Johns Hopkins and Stanford university), chiropractor Dr. David J. Clark, natural medicine practitioner Dr. Rima E. Laibow (M.D. Albert Einstein College), Dr. Lee Hiebs, AAPS (Associations of American Physicians and Surgeons), Dr. Michael Skinner (Washington State University epigeneticist), holistic Dr. James Jeffrey Bradstreet ("vaccine-truther" killed by FDA), and links to anonymous scientists "speaking out".
Adverse events	21	Vaccine injures children	Vaccine injury, vaccine damage, anaphylaxis
	15	Causes diseases	Autism, cancer, ovarian failure, diabetes, immunosuppression, celiac disease
	7	Poisonous	Toxic, toxin, poison, neurotoxin, nagalase, virus overload
	3	Causes death	Commonly using the phrase "vaccines kill".
	2	Vaccines are riskier	Explicit statements that getting measles or other vaccine-preventable diseases is better than getting vaccinated.
Mistrust	17	Conspiracies	US cover up and CDC cover up, Bill Gates is killing Africans by testing vaccines on them, real scientists don't believe in vaccines, doctors killed for exposing the truth, Jenny McCarthy is being witch-hunted, the government is vaccinating as a method of eugenicide
	12	Totalitarianism	#cdnpoli #onpoli #hearus
	7	Pharmaceutical agenda	#bigpharma #pharma
	1	Government is uninformed	Policymakers and scientists are ignorant and uninformed.
Alternative treatment	7	Chiropractic, green vaccines, homeopathic treatment, natural immunity	A variety of immunity-boosting activity that are not administered or distributed through the Ontario Government Pharmaceutical and Medical Supply Service (OGPMSS)
Other concerns	2	Efficacy	Vaccines are ineffective.
	2	Questionable product	Vaccines are made of aborted fetal cells.

Appendices

Appendix 1. Code book for content analysis of vaccine-related tweets in Ontario

Sheet 1. Coding scheme for vaccine sentiment

Category	Definition	Example
Positive	Exhibiting support for vaccination, agreeing with pro-vaccine news and comments, disagreeing with anti-vaccine content	*"We were so ill for so long. It almost killed my little sister. This is before a vaccine was created."*
Neutral	Posts that contain information about vaccination that has both pro-vaccine and anti-vaccine content without supporting or opposing vaccines, asking general questions about vaccine schedule without explicitly being supportive or against vaccines (ambiguous), making observational comments, et cetera.	*"@0ricLeclair1 @ottawahealth @0gpayn1 @OttawaCitizen But what abt ppl who've had both vaccine AND booster & are still catching it? #NHLmumps"*
Negative	Exhibiting clear opposition towards vaccination, such as dismissal of vaccination, sharing anti-vaccine information and views.	*"MIT Doctor Links Glyphosate & MMR VACCINE to Autism Spike Dr Seneff https://m.youtube.com/watch?v=Gh_E-wxVHd8"*
Based on previous researchers who have conducted vaccine sentiment analysis on social media (Faasse et al., 2016; Okuhara et al., 2017; Salathé & Khandelwal, 2011) and vaccine sentiment content analysis (Guillaume & Bath, 2008; Madden, Nan, Briones, & Waks, 2012), we categorized sentiment into positive, neutral, and negative.		

Sheet 2. Coding scheme for profession or affiliation

Category	Subcategory	Description
Public accounts	General public	Twitter accounts set up by people who do not have a distinct purpose for using Twitter.
	Scientists and researchers	Twitter profiles that explicitly indicates that the account is held by researchers and scientists who do not work in health-related fields. E.g., Waterloo prof/momma/triathlete, scientist at CIHI, et cetera.
	Private industries and companies	Official accounts of private industries, companies, and corporations; and official accounts of brands produced by the above. E.g., General Electric, Huggies, et cetera.
	Politicians and celebrities	Twitter accounts that are verified with a Twitter blue verified badge to be celebrities, media personality, politicians[a], et cetera.
	Unidentifiable account types	Accounts that have been deleted by the user, suspended by Twitter, or locked from public access over the course of the research period.
Health-related accounts	Health care professionals	Licensed health professionals that are trained traditionally in universities. E.g., doctors, nurses, physiotherapist, dietitians. And are licensed by governing institutions in Ontario (e.g., College of Physicians and Surgeons of Ontario, Ontario College of Homeopathic Medicine, College of Chiropractors of Ontario, College of Nurses of Ontario, et cetera),
	Public health practitioners	Public health nurse, public health outreach professional working in public health units.
	Alternative health practitioners	Practitioners that have alternative licensure systems that are regulated in Ontario, but otherwise unrecognized or unregulated in the majority of other countries. E.g., Chiropractor, osteopathic doctors, naturopathic doctor, homeopathic doctor, nutritionists.
	Public health organizations	Official accounts established by non-profit international/federal/provincial public health organizations.
	Local public health agencies	Official accounts of 36 “health agencies established by a group of urban and rural municipalities to province a more efficient community health program” (MOHLTC website, 2017) in Ontario, funded by the Ministry of Health and Long-Term Care.
	Local Health Integrated Networks (LHINs)	Official accounts of Ontario’s provincial network of 14 health authorities funded by the Ministry of Health and Long-Term Care to coordinate healthcare services across the province.
	Medical associations	Official accounts of various medical associations, including nursing associations, physician

		associations, pharmaceutical associations, et cetera.
	Hospitals and Health-related research Institutions	Official accounts managed and run by non-profit hospitals, for-profit hospitals, university affiliated hospitals, as well as various research institutions that conduct and disseminate health-related information.
	Pharmaceutical companies	Official accounts established by corporations that produces medicine for profit. E.g., Merck, GSK, et cetera.
News accounts	Mainstream news	Official accounts of internationally or nationally distributed news channels. E.g. New York Times, CBC, ABC, Globe and Mail, Yahoo! News, Huffington Post
	Local news	Official accounts of local distributed news channels. E.g., Niagara This Week, Ottawa Citizen, CP24, Toronto Star, Local CTV (e.g., Toronto, London, Barrie, Ottawa, Kitchener, Windsor).
	Health and science news	Official, usually online distributed news sites dedicated to health and science news and easy-to-read health and science research dissemination. E.g., Medical News Today, Science Daily, Eureka Alert, et cetera.
	Alternative news stations	Official news websites that distribute news or information that are claimed to be news, often recognized to be of an alternative narrative. E.g., VaccineImpact.com, TruthInMedia.com, NaturalNews.com, Inquisitr.com
	Talk-shows/podcasts	Accounts held by hosts of television, radio, or podcasts, distributed on the internet that are produced by any of the following: individuals, companies, corporates, et cetera.
	Bloggers	Twitter accounts of people who explicitly share post on blogs (e.g., weblog) for a living, for information dissemination, or for commercial purposes through the promotion of products through their blogs.
Anti-vaccine accounts	Anti-vaccine	Twitter accounts that are cause-specific to promote anti-vaccine messages
	Conspiracy theorists	Conspiracy theory tweets or accounts, identified by the tendency to post various types of conspiracy theories, or the Twitter account indicates the inclination towards certain conspiracy beliefs, with the inclusion of anti-vaccine messages.

[a] One politician who is also a healthcare professional was categorized as a healthcare professional because the politician works in a health-related government organization.

Sheet 3. Coding scheme for general emotions conveyed in tweets

Category	Subcategory	Description	Sample codes
Emotion[a]	Positive	Joviality	Happy, joyful, delighted, cheerful, excited, enthusiastic, lively, energetic
		Self-assurance	Proud, strong, confident, daring, fearless
	Negative	Fear	Afraid, scared, frightened, nervous, jittery, shaky
		Anger	Angry, hostile, irritable, scornful, disgusted, loathing
		Guilt	Guilty, ashamed, blameworthy, angry at self, disgusted with self, dissatisfied with self
		Sadness	Sad, blue, down, alone, lonely
	Neutral or ambiguous	Attentiveness	Alert, attentive, concentrated
		Shyness	Shy, bashful, sheepish, timid
		Fatigue	Sleepy, tired, sluggish, drowsy
		Serenity	Calm, relaxed, at ease
		Surprise	Amazed, surprised, astonished

[a] Derived from the PANAS-t scale by Goncalves et al, 2013. The PANAS-t scale was used to detect the emotionality of tweets surrounding events (i.e., the Olympic games), politicians (i.e., Barack Obama), celebrities (i.e., Susan Boyle), and disease outbreaks (i.e., H1N1).

Sheet 4. Coding scheme for embedded medium in tweet

Category	Description	Example tweets
No links	A tweet that contains no links.	*"I like how anti-vaccine people don't let sound scientific proof stand in the way of their beliefs."*
Text	Links with text	*"Get the shot! RT @bmj_latest: British govt launches campaign to give MMR vaccine to a million children in England http://www.bmj.com/content/346/bmj.f2696"*
Image	Links containing images as the main content, may contain captions	*"Avoid dromaderies people you never know!#Vaccine #AntiVaccine #EducateYourself http://fb.me/3Y5ByTh77"*
Video	Links containing videos as the main content	*"Courts quietly confirm MMR Vaccine causes Autism (via @news360) http://n360.to/14dWK6K @JennyMcCarthy .@TOPublicHealth @VaccineXchange"*
Multimedia	Links containing texts and text and/or videos	*"Give me liberty or give me vaccine? STROBEL |Home|Toronto Sun http://www.torontosun.com/2015/02/08/give-me-liberty-or-give-me-vaccineMistakes in medicine are being corrected over time."*

Sheet 5. Coding scheme for direction of information-sharing

Attribute	Category	Description	Sample tweet
Direction of information-sharing	Information-seeking	Questions, question marks only, polls and surveys	*"@TOPublicHealth how to protect babies too young for measles vaccine?"*
	Information-sharing	An @response, or tweets containing URLs that shares a piece of news, informational websites, or recommendations, suggestions, referrals, et cetera.	*"RT @NRPublicHealth: Parents of infants with questions about #measles vaccine http://bit.ly/1EdbHIf"*
	Call for action	Activities involving asking other users to take action, for instance, to update their vaccination records, or to attend a rally, or any responses to the above.	*"Journalist looking for #parents who have chosen not to #vaccinate for serious & sensitive chat. Please get in touch. #antivaxx #antivaccine"*
Call for action tweets are considered a type of information-sharing but are separated as its own genre because it explicitly asking for others' participation in an event, et cetera.			

Sheet 6. Coding scheme for use of Twitter functions

Category	Description	Sample tweet
Mention (@)	A tweet containing another account's Twitter username, preceded by the "@" symbol.	*"AUTISM Is Now Disclosed and Acknowledged as a Possible Side-Effect of DTaP Vaccine http://ln.is/prof77.wordpress.com/aol6S @VaccineChoiceCA @DrEricHoskins"*
Reply (@)	A reply to another person's tweet, "@" symbol appears in the beginning of the tweet.	*"@ottawahealth I agree. These vaccines were created 4 a great reason. B/c of this crazy no-vaccine movement childhood diseases r returning"*
Retweet (RT)	A reposted tweet that allows a person to Retweet their own tweets or tweets from someone else. A person may also quote tweet, which allows them to add comments on top of the Retweeted content.	*"Disgusting! RT @picardonhealth Ottawa 'vaccine-free' daycare criticized by @OttawaHealth http://www.cbc.ca/news/canada/ottawa/vaccine-free-daycare-criticized-by-ottawa-public-health-1.2948583?cmp=rss via @CBChealth #antivax"*
There are tweets with multiple functions (n=3). Tweets containing retweets and other functions are always categorized as Retweets if it is a direct retweet without altered content from an original tweet.		

Sheet 7. Initial codes for thematic analysis for negative vaccine sentiment

Reasons for negative vaccine sentiment*	Subcategory	Description	Sample tweet
Perceived threat of disease	Lower than risk of getting vaccines	Explicit statements that getting measles or other vaccine-preventable diseases is better than getting vaccinated.	*"@0trongestros1 @0earntheris1 Its a worldwide fight I'm #honoured to be part of. Because #vaccineinjuredlivesmatter #standproud #antivaccine"*
Alternative treatment	Holistic medicine	The promotion of treatments that are explicitly belonging to the genre of holistic medicine. E.g., homeopathy, naturopathy, osteopathy	*"Healing from Vaccine Injuries through Homeopathy http://fb.me/4q7mEg2vy"*
	Alternative medicine	Promotion of chiropractic interventions	*"How Vaccines Cause Autoimmune Disease | #HearUs #CDCwhistleblower #MyBodyMyChoice #NoMandates #ImmuneSystemOverload http://youtu.be/n0e6I9qHSCI"*
	Natural immunity	Promotion of natural immunity as the best immunization practice	*"@0oegoodin1 @0amMonicaRa1 What are the Real Risks of Not Vaccinating in the US? http://www.visionlaunch.com/what-are-the-real-risks-of-not-vaccinating-in-the-us/ #vaccinechoice #nomandates"*
Concerns about effectiveness	Vaccines are Ineffective	The belief that vaccination is an ineffective method for disease prevention	*"Scientists Against Vaccines- Those Who Have Done the Research http://www.organiclifestylemagazine.com/scientists-against-vaccines-hear-from-those-who-have-done-the-research via @organiclife #antivaccine=#Awake #CDCwhistleblower"*
Mistrust	Profit orientation	The idea that vaccination is an agenda for pharmaceutical companies and the government to make profit	*"pharma is $multibillion$ industry w/ unhealthy ties to our political system ~ @senruderman <YES #CDCwhistleblower #Vaccines #NoMandates"*
	Cover up	The belief that vaccination is dangerous and certain aspects of the dangers of vaccination is being hidden from the	*"http://www.dailymail.co.uk/news/article-3141287/Authorities-Anti-vaccine-doctor-dead-apparent-suicide.html #JeffBradstreet we know u didn't kill*

		public	*yourself. You were murdered like many before you.#ANTIVACCINE #NAGALASE kills"*
	Totalitarianism	The request for less control and regulation over vaccination, and the opposition of mandatory vaccination programs.	*"Preserve vaccine choice. #nomandates https://community.sumofus.org/petitions/preserve-our-charter-rights?bucket=&source=twitter-share-button via @SumOfUs"*
Safety	Causes autism	Concerns that vaccination causes autism	*"30 years ago #autism rates were 1/10 they're closer to 1/50. Vaccine injuries are very real. @ottawahealth @0raymal1 '000 in the US. Today"*
	Violation of natural order	Concerns that vaccinations are unnatural	*"Anti-GMOs #ProVaccine or Pro-#GMOs #AntiVaccine? http://www.thesleuthjournal.com/anti-gmo-but-pro-vaccine/ #CDCwhistleblower #JustLabelIt $ #Agenda"*
	Adverse events	Concerns that vaccinations cause adverse reaction, injury, and damage	*"Anabelle's Story http://www.learntherisk.org/stories/anabelles-story/ #nomandates #CDCwhistleblower"*
	Poisonous	Concerns that vaccinations are poisonous	*"@tedcruz Would you drink aluminum mercury? then why inject them with #vaccines? #nomandates #cdccorrupt #aborted fetal cells"*
Others	Conspiracies	False beliefs that vaccinations are conspired to do harm, often built on concerns towards the safety of vaccines.	*"ATTN PRO-VAXXERS: before you marginalize and ridicule anti-vaccine folks read this: Bill Gates Vaccine Crimes http://vactruth.com/2014/10/05/bill-gates-vaccine-crimes/"*
	Fake experts	The citation or reference to physicians, doctors, scientists, and researchers who are anti-vaccine	*"Robert F. Kennedy Jr. - "Shocking Vaccine Cover Up: http://www.infiniteunknown.net/2009/10/14/robert-f-kennedy-jr-%e2%80%93-shocking-vaccine-cover-up/#.UghPfRj0Ngk.twitter @TOPublicHealth"*
*The categories are based on Schmid et al's 2016 commentary on designing conversations to address vaccine hesitancy with Theory of Planned Action (TPA) as the analytical theoretical framework. The researcher drew from a meta-analysis on reasons for vaccine hesitancy around the world from 2015-2016 for the categorization of vaccine refusal/ denial (Schmid, Rauber, Betsch, Lidolt, & Denker, 2017).			

Chapter 4. Preface

This chapter builds on insights from the previous two chapters but explores a different question using different data sources to examine how decision makers and advisors in the areas of policy and communications are approaching the use of social media as a tool for addressing vaccine hesitancy and for promoting public confidence in vaccines in Ontario, Canada. A case study design was employed drawing on in-depth interviews and public documents.

Four categories of thematic findings illustrate how vaccine hesitancy and misinformation on social media are viewed differently by role and level, how potential uses of social media itself are viewed differently by role, how using social media to address vaccine hesitancy is complicated by many factors, and how other areas besides using social media may yield more robust results. This case study illustrates the particular challenges of implementing social media for immunization promotion within institutionalized settings.

I conceptualized the study, designed the interview guide, collected and analyzed all primary and secondary data. Julia Abelson provided advice and detailed input on the framing of the study question and objectives, the methodological foundations of the study design, including the identification and recruitment of key informants, the design of the interview guide and approach to the analysis. She also reviewed numerous drafts of the manuscript and provided feedback on the interpretation of results. John Lavis provided input on the study design at key stages, contributed to the framing and structure of the study results and reviewed various drafts of the manuscript. Anatoliy Gruzd provided intellectual support and high-level comments on the interpretation of results.

Chapter 4: A case study of the role of social media in immunization policymaking in Ontario

Abstract

Background: In 2014, Ontario's Chief Medical Officer of Health commissioned a formal review of the province's publicly-funded immunization system. The report highlighted the need for the government to establish strategies to foster an informed and confident public, in relation to immunization. As public health decision makers grapple with decreasing and widely varying immunization rates across the province, social media is proposed as one of the tools to address this problem and related concerns about vaccine hesitancy and misinformation. **Objective:** The objective of this study is to explore the perspectives of decision-makers and advisors in policy and communications contributing to provincial and municipal level immunization policy in Ontario in 2016 about the use of social media to respond to vaccine hesitancy. **Methods:** We conducted an exploratory case study, drawing on interviews, and government and organizational documents. Using purposive sampling, key informants advising and/or making policy and communications decisions related to immunization at the provincial and municipal level in Ontario in 2016 were identified. Interviews were conducted using a semi-structured interview guide informed by selected literature on the topic of vaccine hesitancy in the Canadian context. Government and organizational documents were used as a supplementary data source in two ways: i) to complement the perspectives shared by key informant interviews; and ii) to analyze the approaches offered to address vaccine hesitancy in government recommendations as compared to those of individuals responsible for policy and communications decision

making related to immunization policy. **Results:** We conducted 23 in-depth interviews and reviewed 16 government documents. Four key themes emerged from the interviews: first, vaccine hesitancy and mis-information on social media are viewed differently by role and level; second, potential uses of social media itself are viewed differently by role; third, using social media to address vaccine hesitancy is complicated by many factors; fourth, other areas of focus other than social media could yield a greater return. **Conclusion:** To meet the goal of a confident and informed public regarding vaccines, immunization policy in Ontario would benefit from the expertise of advisors and decisionmakers at both the policy and communications level to develop strategies to create a transparent, open, and accessible immunization delivery program.

Keywords: social media, public health policy, immunization program, Canada, policymaking, communications, vaccination

Introduction

The growing phenomenon of vaccine hesitancy attributable to social media has been documented extensively around the world (Aquino et al., 2017; Bolton, Memory, & McMillan, 2015; Hukic, 2017; Larson et al., 2016; Okuhara et al., 2017; Ward et al., 2017). Canada has not been exempt from this trend leading to widespread concern within its public health community (Marwaha, 2017). Adding to this concern, a series of vaccine preventable disease (VPD) outbreaks in Canada between 2010-2015 has placed the issue of vaccine hesitancy, and the need to find appropriate responses to increase public confidence towards vaccines, on the agenda of both federal and provincial organizations responsible for immunization policy in Canada (Government of Canada, 2015).

In Canada's largest province, Ontario, immunization coverage rates vary widely between municipalities, with some immunization coverage rates hovering below the rates needed to create effective herd immunity (Public Health Ontario, 2017). In 2014, the Advisory Committee for Ontario's Immunization System Review was commissioned by the Chief Medical Officer of Health to conduct the province's first formal review of its publicly funded immunization system (The Advisory Committee for Ontario's Immunization System Review, 2014). In this report, the need for the government of Ontario to establish strategies to foster an informed and confident public that sees immunization as a right and a responsibility was one of its core recommendations. This recommendation was subsequently written into the "Immunization 2020" strategic framework developed by the Ministry of Health and Long-Term Care in 2015, which seeks to create an "informed, confident public" (MOHLTC, 2015, p.10) and to "'up its game' in terms of the use of

internet and social media, with the vast majority of the public now obtaining health information online" (The Advisory Committee for Ontario's Immunization System Review, 2014, p.14).

Despite the growing interest in using social media as a means for creating an informed and confident public towards immunization, the feasibility of employing social media to address the problem of vaccine hesitancy has not been comprehensively assessed in the Ontario context. More specifically, little is known about the perspectives of those working in immunization policy arena. Since any effort to implement social media strategies will require the support and expertise of those working in the public health system, we sought to explore how social media is perceived by those contributing to and making decisions related to its functions and use in immunization policymaking. We posed the overarching question to explore this phenomenon: *How are communications and policy advisors and decision-makers who contribute to immunization policy in Ontario making sense of social media in the context of vaccine hesitancy and misinformation?* More specifically, we sought to answer the following questions: *What are their perceptions towards the antivaccine movement and vaccine hesitancy, and the potential for using social media to address vaccine hesitancy? How might social media be used to address vaccine hesitancy and to create a more confident public towards vaccines?*

Methods

Research design

We used an exploratory case study approach combined with grounded theory methods (Halaweh et al, 2008) to examine the role of social media in governance and

policymaking (Figure 1). Case study methods are suitable for addressing how and why questions in real-world settings and are especially useful for "illuminate[ing] a decision or set of decisions: why they were taken, how they were implemented, and with what result" (Yin, 2003, p.12). In the context of prevailing vaccine hesitancy attributable to the influence of social media in Ontario, we study the perceptions of immunization decision-makers and advisors working in policy and communications towards vaccine hesitancy and their views about the use of social media as a tool for addressing vaccine hesitancy and increasing public confidence about vaccines.

We identified the unit of analysis as those who are integral to the understanding of social media's use in response to vaccine hesitancy, that is, the decision makers and advisors at both the policy and communications level, and the use of social media in relation to immunization policy development or implementation, within or in collaboration with government organizations. Informed by literature exploring the paradigmatic foundations of vaccine hesitancy and theories that explains the polarization of misinformation (Supplement 1 and Supplement 2), we make the proposition that perceptions and subsequent solutions proposed to address vaccine hesitancy are driven by a priori understanding of vaccine hesitancy and the health system within which decisions and policies are made. Two assumptions were made in approaching the identification of key informants for the study: first, the scope of key informants to be interviewed should not be limited to those contributing to immunization policy content because social media use in relation to immunization policy is also overseen by communications specialists, as such, both policy *and* communications advisors and decision makers should be included to

capture a diverse range of perceptions. Second, because immunization policies are mostly developed and delivered by governmental and affiliated organizations, we presume that interviewees identify with the importance of immunization coverage and uptake. Thus, to make sense of social media in the context of vaccine misinformation, concepts around the use of social media *for* achieving policy goals (i.e., vaccine uptake), such as the discussion of trust, methods of public engagement, and online health promotion were anticipated to be part of the dialogue.

To mitigate the shortcomings of an exploratory case study design in the area of data analysis and theory generation, we integrated a Straussian grounded theory approach, which not only supports the deductive process of exploring past literature to obtain background knowledge on the phenomenon of interest before data collection, but also provides a well-defined coding process to allow for a consistent and dependable inductive analysis (Halaweh, Fidler, & McRobb, 2008). The study received ethics approval from the Hamilton Integrated Research Ethics Board (HIREB) in November 2015.

Data collection

The case study was built around two main evidentiary sources: i) interviews with key actors in Ontario's immunization policy arena; and ii) government and organizational documents pertaining to the case. These evidentiary sources were identified and used in a mutually informing way through data collection and subsequent research stages.

Key informant identification

Key informants were identified through a purposive sampling approach using the following process: first, we conducted a news media environmental scan using keywords

"anti-vaccine, vaccine, immunization, Ontario" and documented names and organizations that appeared in popular national and local news sites (e.g., CBC, the Globe and Mail, The Toronto Star) between March 2015 and November 2015. We downloaded any government publications on immunization that were mentioned in the news. Names appearing in news media, government websites, and government documents were logged and searched for online (e.g., LinkedIn profiles, government websites, university faculty pages) to determine the relevance of their position to the immunization policy landscape in Ontario. Wayback Machine[56] was used to retrieve any webpages that were deleted, relocated, or had no cache available. We prioritized two types of interviewees for recruitment: i) immunization policy advisors and decision makers and; ii) communications advisors and decision makers familiar with or working directly in the area of immunization policy.

Interview invitations were sent by email to prospective interviewees or their administrative staff with a reminder email sent after 14 days and a final phone call after 3 email attempts. Interviewees were invited to participate in a 45-60-minute interview either by phone, on Skype, or in-person. The interview questions and consent form were sent prior to the interview, including consent for follow-up interviews if needed. All interviewees were asked to identify the names of 3 additional individuals who they considered important to the question of inquiry. Names mentioned more than twice that did not show up in our initial search were added into the list of identified key informants after conducting an online search about the person's credentials and experiences in relation to immunization policymaking. Recruitment of interviewees was terminated when data saturation was

[56] The Internet Archive: Wayback machine. URL: https://archive.org/web/

reached.

Interview guide development

A semi-structured interview guide was constructed in 3 stages. First, to gain a thorough understanding of the immunization policy landscape in relation to vaccine hesitancy and the use of social media, globally and locally, we searched for scholarly publications from Google Scholar, PubMed, ArXiv, ProQuest (political science and PsychInfo) in three areas: (1) theories and concepts on the rise of vaccine hesitancy, (2) theories on the polarization of beliefs and/or spread of misinformation on social media, (3) reviews of case studies and applications of social media in governance and policymaking. This literature review yielded key insights into the challenges, barriers, and failures of past and current social media initiatives from an institutional perspective and about how social media can inform the formulation, implementation, evaluation of immunization-related policies that increase vaccine confidence. We also searched for anti-vaccine related news using Google news search (online news) and Library and Archives Canada (print-news) using keywords "anti-vaccine OR antivaccine OR anti-vax OR anti-vaxxer AND government" as well as a combination of related keywords (i.e., Ontario, policy, immunization) to understand the types of organizations, narratives, policies, and events are being discussed in the news media. Results from these searches provided important background information about relevant events occurring before and during the interview process. Third, we used the framework of social media use for governance from Bertot and colleagues (Bertot, Jaeger, Munson, & Glaisyer, 2010), with a focus on questions that would facilitate the exploration of perceptions about social media use to address vaccine

hesitancy in an institutional perspective. Interviewees were encouraged to explore relevant topics beyond the interview guide and to expand in particular on themes related to their respective decision-making processes (e.g., stakeholder relations, organizational mandates, social media practices, policies and regulations). (See semi-structured interview questions in Appendix 1). Pilot interviews were conducted with 2 key informants to refine and finalize the interview guide.

Document selection and retrieval

Documents were collected at various stages to provide conceptual and analytical support to the initial research design phases (e.g., through the literature review stage), to assist with the key-informant identification process, to fill knowledge gaps and corroborate findings emerging from the interviews, and throughout all data analysis stages (i.e., during memo-taking and the coding process). First, during literature review, we identified documents that were relevant to the question of inquiry. If these documents were mentioned during the interview or were provided by the interviewees, we prioritized these documents for analysis. Second, internal social media policy protocols, policies for crisis communication, and internal minutes that were provided by the interviewees were reviewed and placed in context of the descriptive experiences of the interviewee. Documents were also retrieved to provide important background and organizational and budget information about immunization policy and social media protocols and to create a timeline of key events and policy decisions. Third, any additional government documents that were not captured by the first two methods that may contribute to the confirmation or refutation of the research proposition, in conjunction with the thematic findings emerging from the interview

transcripts, were incorporated into the process of data analysis. A total of 16 government documents, including audits, reports, protocols, and presentations were included in the data analysis (See Appendix 2).

Data analysis

Interviews were audio-recorded and transcribed using O-transcribe and coded using MAXQDA 12. During the process, we employed the method of constant comparison and pattern-matching to compare the similarities and discrepancies between interviewees' perceptions about the anti-vaccine movement, vaccine hesitancy, and ways to address vaccine hesitancy with the content of the documents collected.

Three levels of coding were applied to the interview transcripts. First, open coding was carried out to examine, compare, conceptualize and categorize the data (Strauss and Corbin, 1990, p.61) with three areas of emphasis: the main ideas in the text; the attributes of the interviewee (i.e., gender, sector, years in experience, date and time); and the descriptive (e.g., nouns, terminology, institutions, names, positions, incidences that describes what is happening, et cetera) and procedural elements (e.g., time-related, processes, explanations of procedures, occurrence of events that describes how it happened) of the data (Miles, Huberman, & Saldana, 2013; Saldana, 2009). Stand-out quotes were highlighted and coded directly in the transcript (in-vivo), and concepts and phrases that reflected perspectives that were unique and different from other interviewees or confirmed other interviewees' viewpoints were highlighted at this first stage. Second-level coding consisted of two elements: axial coding, which looks for connections between categories generated in open-coding; and focused coding which searches for the most frequent and

significant initial codes to develop the most salient themes. A conceptualization of themes was then carried out through an iterative process of re-assembling codes, quotes, words, and phrases in relation to the phenomenon of exploration and the proposition of the case study. The process draws constant comparison between the categories, revisiting transcripts to discover latent themes, and comparing them to government documents as needed. Finally, third-level coding, or selective coding, was used to bring together categories into an explanation or theory. This ultimately led to the generation of 4 discrete themes that were used to explore the perspectives of immunization policy advisors and decision-makers, and communications advisors and decision-makers about using social media as a response to the prevailing anti-vaccine phenomenon in Ontario.

We used data triangulation to compare and contrast different evidentiary sources to strengthen the credibility of our findings (Eisner, 1991; Leech & Onwuegbuzie, 2007; Wilson & Hutchinson, 1991). When themes emerging from the interviews were found to be consistent with the content analyzed in the documents, this provided confirmatory support for our interview findings. Where discrepancies are identified, "thick description" (Stake, 1995) was used to explore how and why these discrepancies exist.

Results

Interviewee attributes

Between January and September 2016, 23 interviews were conducted (9 in person, 3 by Skype, and 11 by telephone). Most interviewees were based in Ontario (18), with 2 each from Nova and British Columbia, and 1 from Quebec (See Appendix 3 for a list of interviewees by jurisdiction, position and organization type). The 5 interviewees from

outside Ontario were recommended based on their involvement in Ontario's vaccine-related policy and communications content, as well as their contribution to policy discussions for addressing vaccine hesitancy in Ontario. Two interview invitees declined based on self-identified lack of familiarity with the topic and four did not respond to the interview invitation.

Policy advisors and decision makers interviewed were generally at a mid-to-late career stage with more than 20 years of experience in the field of immunization; a majority of them large held medical or doctorate degrees or both. Communications advisors and decision-makers were typically younger, with around 2-10 years of experience in communications about vaccines and/or immunization policies and had held positions in communications and social marketing before being employed in their current position. Communications specialists were most likely to hold undergraduate or graduate degrees in communications, marketing, and management, or diplomas in communications and/or public relations. All interviewees except for one worked in organizations that contribute to immunization policy in the following ways: advisory roles (e.g., research, evidence-gathering) in policy and communications; in decision-making roles related to immunization policy, and in decision-making roles related to communications. We have categorized them into two groups according to the nature of their work: policy content contributors (PCCs) (n=14), and communications content contributors (CCCs) (n=9) (See Table 1).

Thematic results

Our inquiry into how policymakers are making sense of social media in the context of prevailing vaccine hesitancy in Ontario yields a rich set of results that have been

organized around four overarching themes supported by both interviews and documents as evidentiary sources. The four themes are: i) vaccine hesitancy and misinformation on social media are viewed by role, level, and experience, ii) the potential use of social media is viewed differently by role, iii) the use of social media to address vaccine hesitancy is complicated by many factors, and iv) other areas of focus might yield greater return with respect to addressing vaccine hesitancy. Our analysis of the interviews contextualizes the problem of vaccine hesitancy, drawing on experiences and individual practices. Our review of key policy and organizational documents provides insights into the barriers faced in using social media and to the level of priority given to vaccine hesitancy as policy problem. Considered together, our findings from these two evidentiary sources allow for broader reflection on whether and how social media can be used to inform and contribute towards a public that is more confident in vaccination. Quotes are shown in italics followed by interviewees' de-identified number in brackets (P#) or (C#).

Theme 1: Vaccine hesitancy and misinformation on social media are viewed differently by role and level and experience

Interviewees unanimously perceived the current problem of vaccine hesitancy to be attributable to Andrew Wakefield's fraudulent journal article published on The Lancet that was later retracted. This sentiment is captured by the following interviewee: "*I don't think there's anybody in the immunization field who is not concerned about it." (P5)*

Although all interviewees acknowledged vaccine hesitancy as a significant public health problem, PCCs and CCCs working at different governance levels perceive the problem and approaches for addressing it in fundamentally different ways reflecting

different understanding of the contributing factors toward vaccine hesitancy, and the scope of the problem.

Some portrayals of the problem focused on individuals and groups with concentrated financial or political interests who are perceived to be driving the anti-vaccine movement in Ontario while others suggest that a single group may be behind the entire anti-vaccine movement which has created a number of websites to *"look like there's all these different groups out there (P4)".* Lack of trust in government among particular demographic groups was also cited as one of the reasons for the proliferation of vaccine hesitancy. *"They are often […] similar membership of people who are against fluoride in the water, against wind turbines. It's almost as if they're against any government involvement (P1)".* Yet others perceive that the vaccine hesitancy is perpetuated by a critical public called "the questioners (P2)" who are usually highly educated and eager to know more, and *"if they don't get the answer in a way that they want, in the way that they believe, they're going to say 'well, I'm not doing this, you have to convince me'. (P2)".* Some believe that social media have contributed to vaccine hesitancy in English-speaking countries, and in particular, it is *"the things you read online (P7)"*, or narratives on vaccination that fits the lifestyle of new-wave, health-conscious citizens who browse the internet to navigate ways to achieve wellness. Some suggest that the invasive procedure to vaccinate is sending "mixed messages (P3)" to demographics who are being told that non-invasive, all-natural processes promotes health better than invasive procedures (e.g., surgery, injections).

PCCs highlighted differences between the vaccine hesitant and those opposed to

vaccines. They expressed sympathy towards the vaccine hesitant, especially towards those whose children died from vaccine-preventable diseases, portraying them as ill-informed parents *"trying to do their best (P6)"* who are unable to make sound judgements for their children. On the other hand, those who are opposed to vaccines or who participate in the anti-vaccine movement are perceived as deliberate perpetrators of misinformation who take advantage of the public's mistrust towards the government and are enablers of a false sense of empowerment (i.e., the decision not to vaccinate).

CCCs exhibited a comparatively more public health promotional view towards addressing hesitancy. One communications content contributor said*, "what does success look like?'*. And*, "success from a public health standpoint is getting the word out, or people changing their behavior in the longer term. (C5)"* They use the terms vaccine hesitancy and anti-vaccine interchangeably, and consider the source of the problem to be simply a matter of knowledge deficit. This perception is partially driven by the division of labour between themselves and content experts (i.e., public health nurses and Medical Officers of Health (MOH)). CCCs rely on content experts to generate and approve the content that they are responsible for managing on social media platforms thus fuelling perceptions that efforts to address vaccine hesitancy are simply a matter of making the safety of vaccines known to the public.

Theme 1.1. Addressing vaccine hesitancy through health promotion or health protection – a matter of perception

Interviewees shared a general view that *"immunization works when people don't think about it (P3)".* However, within the high-profile context of vaccine hesitancy, the

need for a different approach was expressed and two dominant perceptions of the public were emphasized. Some identified a "critical" public that needs to be actively engaged through health promotion strategies and policies designed to *"get the public to our (government) side (P3)"* (e.g., support vaccination). Others identified a more defiant public that needs health protection. For instance, if those opposed to vaccines are identifiable, there should be policies in place for penalties and punishments, so that anti-vaccine proliferators *"suffer the consequences (P2)"* to protect the innocent public from the defiant public.

Theme 1.2. Vaccine hesitancy is complex and there is no silver bullet

> *"At an individual level and a community level, we do know where these people (vaccine-hesitant) are. But, where it becomes challenging is we want a silver bullet […] that will address the concerns of everybody, and it doesn't work that way, it's a very complex issue (P9)"*

PCCs perceive vaccine hesitancy as a complicated issue that can't be explained by a knowledge deficit alone. They believe that there are distinct strategies to be developed to address the concerns of the vaccine hesitant and those opposed to vaccines, emphasizing that based on experience and research evidence, the former is more open to behavioral change, whereas the latter is demonstrably resilient to change. PCCs with more than 20 years of experience expressed a more relaxed perception towards vaccine hesitancy: **"***Can we just be at ease that the world isn't as streamlined, logical, and that precedence of vaccine disasters have happened and therefore accept that not all vaccine policies will be favoured like before? (P3)"*. Senior PCCs described a few historical public health disasters that have damaged the Canadian public's confidence in public health policies, and

hypothesized that these incidents may have conjured the imaginations of the contemporary public to become hesitant towards vaccine policies. However, because vaccine uptake has not decreased precipitously in Ontario, and that vaccine misinformation has ebbed and flowed for as long as vaccines have existed, it was observed that *"they will keep ebbing and flowing. (P6)"*

Theme 2: Potential use of social media itself are viewed differently by role

Social media is being used for a variety of purposes related to immunization policy in Ontario but largely plays a supporting communications role to other activities such as the management of outbreaks, immunization awareness campaigns and for the dissemination of research within the public health community. Its use is also heavily dictated by the requirements of Ontario Public Health Standards (OPHS) and its Protocols. The potential for social media to play a more significant role beyond being used as a portal for information dissemination was met with uncertainty by most interviewees. CCCs and PCCs shared different views about how social media might be used to address the problem of vaccine hesitancy.

Theme 2.1. Social media as sources of insight to craft strategic plans and communications tools

CCCs explained that good communications plans should include a thorough understanding of the social media landscape, the communications preferences and user behavior of the outreach population, and an overall strategy that is supported by evidence and stakeholders.

To justify the use of social media for information dissemination, project managers

usually submit applications to CCCs to explain how social media would help achieve programmatic goals. CCCs use terms like "engagement" and "listening in" to describe the benefits of using social media. Engagement means using social media management tools like Sprout Social or Hootsuite to set up scheduled messages for posting, build analytics (e.g., numbers of link shares or Retweets, number of clicks and replies), and follow conversations using keywords and hashtags. Listening in, on the other hand, describes content monitoring of official social media accounts, and in circumstances where misinformation is being spread, CCCs will evaluate whether to delete or respond to this content.

Some CCCs stated that balancing the 3 pillars of governance, namely, "*openness, authoritativeness, and trustworthiness (C5)"* is a delicate task. To assuage the vaccine hesitant from attacking vaccine awareness content on social media, strategies need to be carefully designed. These challenges led those with more policy-making responsibilities to be less willing to be involved in social media conversations or health promotional approaches using social media. For example, the MOHLTC's marketing team collaborated with pro-vaccine parents who actively engage in a Canadian forum for new parents to post pro-vaccine articles from a parents' point of view on behalf of MOHLTC (Yummy Mummy Club, 2015). These marketing strategies were more removed from traditional public health interventions that require the participation of health professionals yet were considered more influential than traditional interventions because the MOHLTC could remain authoritative, while borrowing the voice of a parent-peer, and at the same time allowing interventions to be *"where the conversations are at (P8)".* However, social media is just one element in the

communications plan for vaccine awareness, and most CCCs were unable to articulate how the impact of these marketing strategies are being measured aside from the aforementioned "engagement" and "listening in".

Theme 2.2. Questioning the utility of social media

PCCs were more critical of how social media is being used in contemporary public health outreach in Ontario: "It is *very much the 'down-the-line', passing the message and then it got broadcast to the community. And of course, that's not the way social media works (P8)."* However, they also questioned the general utility of social media for informing immunization policymaking, due to the highly technical nature of immunization policy making and the inappropriateness of social media as a tool for contributing to policy development. PCCs further emphasized that immunization policymaking happens in person, in a controlled and organized manner, with politicians and experts, and to an extent, *"the strength of your evidence (P6)".* They cast doubt on the merits of engaging the public on a highly technical issue, on the one hand, and yet one on which public opinion is so polarized: "*I don't know whether just sticking a person, ... on a highly technical committee really addresses the issue of engaging the public on decisions about immunization. (P3)."*

Theme 3: Using social media to address vaccine hesitancy is complicated by many factors

Whether supportive or skeptical about social media use as more than a communications vehicle, numerous barriers were identified to its use in increasing public confidence in vaccines. Among the barriers identified, institutional, organizational and operational barriers were most commonly cited along with concerns about the lack of

supporting evidence. The factors that complicate using social media to address vaccine hesitancy include: (1) competing priorities that draw attention away from addressing vaccine hesitancy, (2) lack of federal and provincial guidance on the use of social media to address vaccine hesitancy, (3) lack of opportunities for local units to contribute to and adapt provincial social media initiatives to address vaccine hesitancy, (4) lack of collaboration between communication experts and immunization experts, (5) the many practical challenges to achieving success with social media, and (6) legal constraints on the use of social media by government.

Theme 3.1 Competing priorities draw attention away from addressing vaccine hesitancy at all

At the Public Health Unit level, immunization management is operated in accordance with Ontario Public Health Standards (OPHS). Established under the Health Protection and Promotion Act (HPPA), the Standard consists of 4 Foundational Standards[57], 5 Program Standards[58] and 16 Protocols. The Standard specifies minimum expectations for public health programs based on the principles of need, impact, capacity, and partnership and collaboration (Population and Public Health Division, Ministry of Health and Long-Term Care, 2017).

PCCs and CCCs working at the PHU level emphasized that the bulk of their work is focused on supporting the mandates of HPPA and the requirements of the OPHS. As one

[57] Foundational Standards include: Population health assessment, surveillance, research and knowledge exchange, and program evaluation.

[58] The five OPHS Program Standards are: chronic diseases and injuries, emergency preparedness, environmental health, infectious diseases, and family health.

of the Foundational Standards, there is a major emphasis on the "Vaccine Preventable Diseases Standard" in public health practice in Ontario, which is supported by the "Infectious Diseases Program Standard" and the "Immunization Management Protocol" (Population and Public Health Division, Ministry of Health and Long-Term Care, 2016). Fulfilling each Standard and Protocol is labour intensive and time-consuming, and competing public health issues emerge or fade away based on the region's attention cycle and the urgency of the issue. For example, in one municipality, rabies infection was the most pressing issue during the time of the interview, therefore, addressing vaccine hesitancy was given a low level of priority by the PHU.

In addition, public health is considered *"the poor cousin of the overall Ministry (C9)"*, and within a limited pool of funding for public health are many Foundational Standards and Protocols to fulfill. With such limited resources, prioritizing one area where considerable resources are required, such as vaccine hesitancy, over others, may be viewed as unreasonable, particularly where there is uncertainty about the return on investment.

Theme 3.2 Lack of federal and provincial guidance on the use of social media to address vaccine hesitancy

Interviewees identified the lack of federal and provincial guidance as a key barrier to using social media to increase public confidence. Currently, there are no written guidelines on the use of social media to address vaccine hesitancy at the provincial or federal level in Canada. CCCs in PHUs identified the need for provincial authorities to provide guidance on public health outreach in the form of data analytics, research and evidence, and methodological approaches, with social media as part of the communications

plan. In the absence of this guidance on social media practice, two local initiatives[59] have been created (OACPH, 2015; Public Health Ontario, 2011) to facilitate the exchange and documentation.

In addition to the lack of guidance for using social media, existing guidance on immunization policy is based on a single framework[60] developed over a decade ago that requires adaption to match the current challenges of immunization delivery in terms of acceptance in Canada. While offering broad guidance to the immunization community, the framework's ability to address contemporary issues related to immunization policy in Canada warrants some assessment. Document analysis showed that this framework is recommended or used by 5 major organizations and committees with immunization-related mandates at the federal and provincial level. At the federal or pan-Canadian level, these include the Public Health Agency of Canada (PHAC), the Canadian Immunization Committee (CIC) (Canadian Immunization Committee & Public Health Agency of Canada, 2014) (p. 27), and the National Immunization Strategy (NIS) task group that oversees the newly established (2016-2022) Immunization Partnership Fund (IPF)[61] (Public Health Agency of Canada, 2017). Provincially, the framework has been adopted by the Ontario Provincial Infectious Diseases Advisory Committee on Immunization (PIDAC-I) (Public

[59] The first initiative is the Public Health Ontario-funded, Public Health Unit-lead Locally Driven Collaborative Projects (LDCP) which created a guidebook for social media practice in public health called the "Social Media Toolkit". The second initiative is the Ontario Association of Communicators in Public Health (OACPH), which focuses on exchanging strategic approaches in public health communications for PHUs in Ontario.

[60] The framework is developed by Erickson, De Wals, & Farand in 2005.

[61] The IPF invites provinces to submit applications that will increase vaccine awareness and address gaps in vaccine knowledge, attitudes, and practice. No evaluative guidelines were made available for applicants to evaluate the quality of the application (National Immunization Strategy, 2017).

Health Ontario & PIDAC-I, 2012), and was recommended by the 2014 Advisory Committee for Ontario's Immunization System Review to inform a "consistent, evidence-based review framework" (The Advisory Committee for Ontario's Immunization System Review, 2014, p.20). While the framework emphasizes the importance of information provision and that successful programs will ensure that they "supply the best possible information on vaccine products to ensure informed choices by populations, via publications, Internet sites, or information sheets given during visits for vaccines[62]", its limited emphasis on the need understand vaccine hesitancy or on the role of new media in gauging or addressing public confidence in vaccines point to weaknesses in its ability to address contemporary immunization challenges.

Theme 3.3. Lack of opportunities for local units to contribute to and adapt provincial social media initiatives to address vaccine hesitancy

> *"Sometimes the ministry they create the campaign and they just kinda foist it on the province […], I wish we could kind of be in more of that process to say that, 'well, we actually know how to get those messages out really effectively at the local level on a daily basis, and we know the social network, we know the nuances (C9)"*

Interviewees from local public health agencies consider the MOHLTC as the central decision-making authorities for immunization, however, given the active role played by PHO in providing guidance to public health agencies regarding communications approaches, they expressed concern about the lack of opportunity to participate in the decision-making process. They described immunization-related policies as being made in a highly centralized manner, leaving municipalities with few opportunities to provide input.

[62] Category 10 'Ethical considerations', p.2472.

An example cited were public health campaigns designed by the MOHLTC that were distributed to local public health agencies that were "massive flops (C3)" because the campaign materials were not suitable for the demographics of the individual PHUs. These campaign failures were a manifestation of the MOHLTC's inclination to create promotional materials and consultation processes on immunization policies "in-house", rather than through collaborative efforts between different levels of decision-making.

Lack of collaboration was viewed as constraining efforts to use social media to increase public confidence in vaccines. The 36 PHUs across the province are responsible for increasing vaccine uptake and understand where the vaccine hesitant are in their local communities. However, interviewees cited examples of the provincial and local levels working at cross purposes with each other, such as the provincial government favouring the distributing generic vaccine promotion videos over local agencies' desire to focus on communication with at-risk communities (Cadence, personal communication, 2016)

In contrast to the perspectives of local public health agencies, those working outside of the PHUs considered the collaboration between provincial policymakers and the PHUs to be sufficient. They shared experiences of being involved in invaluable knowledge sharing opportunities within an influential policy network including local and provincial Medical Officers of Health (MOHs) who shape the public health policy agenda and pursuing the goals of evidence-informed immunization policymaking and program delivery. Local PHU interviewees emphasized the importance of on-going interaction with the local and provincial MOHs as the best way to gauge how certain public health issues will be dealt with and which public health issues were likely be on the government's

agenda.

Theme 3.4. Lack of collaboration between communication experts and immunization content experts

The fourth barrier to increasing public confidence using social media lies in the division of labour between communications experts and immunization content experts. While PCCs have expert knowledge in immunization and vaccine hesitancy, their knowledge in social media communications is limited. On the other hand, CCCs have expert knowledge in creating communication strategies to support the mandates and protocols of Ontario Public Health Standards (OPHS) such as increasing vaccination uptake and decreasing the prevalence of vaccine preventable diseases. CCCs spoke of their general roles in developing social media policies, approving immunization content for dissemination and developing strategic plans for immunization program delivery (A Higgins, personal communication, 2016). However, the majority of CCCs have indicated that they do not possess the immunization or vaccine hesitancy-specific knowledge that would allow them to enhance their communications plans using social media, and to promote tailored messaging to specific target audiences.

Theme 3.5. Many practical challenges to achieving success with social media

> *"I find it's a mile wide and an inch deep. […] The best you can do is raise awareness, but really competing for 5 seconds of attention. It's one of the things you have to be out there, you have to be part of the cacophony, but I question whether it's really making behavioural change." (C9)*

Interviewees questioned whether social media is an effective tool for gaining

traction on an issue that requires discussion, empathy, reciprocity of informational exchange, and a deeper level of connection with the target population. Most PHUs credit themselves with having a good understanding of the at-risk population with low vaccination rates and high mortality rates (e.g., seniors, busy parents, concerned parents who alter immunization schedules, indigenous populations in territories that do not have the means to access vaccines, etc). Since each target population requires different engagement approaches, and many key target populations may not use social media or follow PHU social media accounts such as PHUs with larger rural populations and lower social media uptake, and those heavily populated with seniors, using social media to reach at-risk populations may be unproductive.

Both PCCs and CCCs expressed that it is difficult to identify how and to whom vaccine awareness interventions should be targeted to on social media. These are driven in part by the methodological challenges associated with designing interventions that include: (1) a lack of standardization in the measurement of the spread, reach, and engagement of vaccine sentiment on social media platforms; (2) difficulty in separating confounders with interventions (e.g., promotional information) in experimental designs on social media, and (3) lack of evidence from longitudinal cohort studies to inform the length of time required for attitudinal changes (e.g., vaccine acceptance) to translate into behavioral changes (e.g., vaccine uptake). Interviewees who simultaneously hold positions as PCCs and academics have the most profound understanding of vaccine hesitancy, and consider the uptake of vaccines an important policy goal that requires a multi-pronged approached such as the adoption of vaccine education in schools, facilitation of an educative environment in

clinical settings by physicians during the "Well-Baby Care" program to expectant mothers and mothers with young children, and provision of continuing education for health professionals to prevent professionals from refusing to vaccinate.

Most interviewees were doubtful about the actual impact of using social media to engage the public. For instance, CCCs shared a story about a vaccine Q&A session on Twitter that was "hijacked (C5)", during which those who were opposed to vaccines asked for proof that vaccines are 100% safe. They noted that the public who support vaccines have counterattacked the vaccine opposers with hostility, in a way that CCCs consider the event neither effective nor ineffective. In essence, almost all interviewees think that real engagement happens on the ground, face-to-face, and one by one; it also has to happen early, with a defined target audience, to have measurable outcomes of changing the public's opinion on vaccine hesitancy and increase vaccine uptake.

PCCs are willing to use social media to understand ways to design awareness campaigns to increase vaccine confidence, however, online sentiment towards vaccination is not representative of vaccine sentiments in the general public[63]. One PCC said, "*this is where the engagement piece gets tricky, […] we don't want to waste busy people's time talking about something that's not an issue (P3)*". Because policymakers are already struggling in the "chase-and-fix" schema of immunization policies in Ontario, and little evidence suggests that public involvement will generate visible impact on addressing

[63] At the time of writing. there is only one federal-level opinion poll that surveyed parents' knowledge, perception, and practices/behaviours on immunization called the "Survey of parents on key issues related to immunization", commissioned by PHAC (EKOS Research Associates Inc, 2011). A self-commissioned survey by Angus Reid in 2015 of 1509 respondents was published in 2015 (Angus Reid Institute, 2015).

vaccine hesitancy, PCCs are hesitant to propose public engagement as a method to optimize social media outreach. In contrast, CCCs have recognized that social media is potentially one of the channels to monitor public sentiment and solicit public opinion, because it helps policymakers understand *"what's working and what's not (C4)*" in order to *"get the public on our side (C5)"*. In addition, although some interviewees shared exemplar uses of social media vaccine awareness promotions in other provinces, such as the development of viral advertisement campaigns and innovative interactive websites in the Province of British Columbia, interviewees consider social media a tricky channel to increase public confidence in vaccines, due to the lack of evidence demonstrating a link between social media interventions and increased vaccine uptake, and the challenges of measuring these correlations. Developing measurable indicators and goals in terms of engaging the public in the process of immunization policymaking is needed to justify budgeting for the mobilization of both material and human resources.

Theme 3.6 Legal constraints to the use of social media by government

Legal constraints also hinder the use of social media in government practices. First, social media use is dependent on organizational social media terms of use; it must also adhere to additional laws such as privacy and information protection laws, eHealth law, and health professional conducts from the Colleges regulates public health outreach provision. As such, PCCs and CCCs are more hesitant to experiment or practice social media due to concerns related to breaking these laws and regulations (See Supplement 1 for laws related to government use of social media and Supplement 2 for laws and standards governing immunization programs delivery).

A second concern is that public health professions like MOHs and public health nurses are bound by the responsibilities and legal regulations of the licensure bodies in Ontario. For example, every interaction a public health nurse conducted through social media has to be documented as per the rules of the Ontario College of Nurses, and every PHU has developed their own rules of conduct related to social media best practices. A third concern is that when PHUs want to borrow promotional material to cross-post on social media, the issue of copyright laws is worrisome to CCCs. Even though borrowing materials on social media is common practice, PHUs prefer to generate their own content, but often do not have the resources or time to do so. These legal and privacy regulations protect both the PHU and the clients, but also decrease incentives for engagement.

In addition, no governing bodies are available to assist PCCs and CCCs navigate the rules and laws that govern social media conduct, public health conduct, and health professional conduct. These factors lead to a sub-optimal use of social media at the regional level and provincial level.

Theme 4: Other areas of focus could yield a greater return

In 2014, the Office of the Auditor General reported that Ontario's immunization programs were rife with fiscal irresponsibility, unable to provide timely and accurate assessment of population immunization coverage, and experiencing ongoing challenges with the use and retrieval of immunization records from the digital health information registry (Office of the Auditor General, Ontario, 2014). Interviewees expressed similar views, unanimously expressing that Ontario's immunization program needs strengthening before it can be trusted by the public. Referring to MOHLTC's "Immunization2020" report

and its goal to create a "confident public" to address vaccine hesitancy, one PCC stated that *"our (immunization) policies are usually a chase-and-fix(P6)."* This chase-and-fix approach appears to describe much of the current approach to immunization policy making in Ontario suggesting that vaccine hesitancy may not be the most pressing policy problem to address.

Theme 4.1. Alternative delivery arrangements and improved education offer promise

Interviewees identified other *"low-hanging fruit(P9)"* as more feasible avenues for increasing vaccine uptake than trying to increase the public's vaccine confidence through social media. The first example of how to increase uptake was to improve the accessibility of vaccine services through more accessible locations and longer hours for immunization services and to invest in mobile and web applications for the public to retrieve and store immunization records and to set up immunization reminders. A successful example of a mobile application is CANImmunize[64] developed by researchers at the Ottawa Hospital Research Institute. Described as a *"disruptive innovation(P7)"*, it was not initially championed by policymakers but because it was developed "*at the right place, [and] at the right time, and they (policymakers) liked it! (P7)"*. The technology resonated with PCCs concept that immunization works when the public doesn't have to think about it, and subsequently received funding from the Canadian Public Health Association (CPHA) and Immunize Canada (P9, personal communication; (CANImmunize, 2018).

[64] An application that has received the financial support and programmatic support is the CANImmunize mobile app[64], developed by an eHealth student of a professor/ physician from University of Ottawa who regularly saw parents struggling to find and store their children's Personal Immunization Record card. The app was launched regionally in Ottawa but is adopted and scaled-up to be implemented in Canada.

The second approach proposed for increasing uptake is through education to target demographics. Most interviewees supported schools adopting a curriculum that *"start early(P6)"* and *"start in classrooms(P6)"* to teach children to differentiate misinformation from real information. Another target demographic is first-time pregnant mothers and mothers who are regular users of the internet. Interviewees described opportunities for this through clinical settings like Ontario's "Well-Baby Care" programs to "*get to them before they get to the internet (P7)"*. Health professionals were identified as a third target group for education driven by concerns expressed about nurses who refuse to vaccinate, and licensed health professionals in Canada that use social media as a portal to promote alternatives to vaccines. As gatekeepers to the health system and the public's first point of contact with vaccine information, interviewees viewed it as crucial to ensure that health professionals are adequately informed. Some went a step further and questioned whether education alone was enough: "*What are the consequences for health professionals who are anti-vaccine? There has to be consequences (P1)".*

Theme 4.2. Better tracking could underpin a broad range of improvements to the immunization system

One of the most pressing problems cited by interviewees, in particular PCCs, is the lack of a comprehensive Immunization Information System (IIS). Prior to 2015, each of the province's 36 PHUs was required to manually enter the number of vaccinations administered in a non-linked database called the Immunization Records Information System (IRIS). This process yielded non-sharable data and prevented physicians who were administering vaccines from being able to access IRIS to enter comparable information. As

the number of publicly funded vaccines in Ontario increased from 9 to 17 between 2006 and 2017 (Government of Ontario, 2009, 2016; Public Health Agency of Canada, 2006), keeping track of vaccination and Adverse Events Following Immunization (AEFIs) became a more complex task than before.

In 2007, the MOHLTC commissioned Canada Infoway, a federally funded non-profit organization, to build a new information system - Panorama[65] - that would replicate a similar system in the U.S.A. such as PRISM[66] and allow the linkage of the vaccine Drug Identification Number (DIN), the identification of the vaccine administrator, and the identification of individuals being vaccinated. Panorama was also meant to replace IRIS, establish new categories for new publicly funded vaccines, and to be made accessible by all health professionals administering vaccines[67]. A major setback in the development of Panorama occurred in 2009, in relation to the province's broader eHealth initiative (Bretscher, 2011; CBC, 2009), which the program has not yet recovered from.

In 2015, a system that cost $260 million and 8 years to build in Ontario alone, Panorama has meagrely replaced IRIS and was able to generate real-time reports on

[65] A "Communicable Disease Surveillance and Management System" developed by IBM in 2009 designed for implementation and use by provincial and territorial jurisdictions across Canada to integrate vaccine and materials inventory (IBM, 2009). Its use and capacity to link data and inventory differs across Provinces and territories. URL: https://www-03.ibm.com/industries/ca/en/healthcare/files/panorama_application_overview_final.pdf. Although the combination of IRIS and Panorama is called the Digital Health Immunization Repository (DHIR), interviewees refer to Panorama to describe the portion of the database that is newly constructed.

[66] Post-licensure Rapid Immunization Safety Monitoring System (PRISM) is an active surveillance project of USA Federal Drug Agency's Center for Biologics Evaluation and Research since 2010. It analyzes data from healthcare plans for vaccine safety post-administration. URL: https://blogs.fda.gov/fdavoice/index.php/2017/04/prism-identifies-vaccine-safety-issues/

[67] In comparison to the current format, which is only accessible by health professionals (e.g., public health nurses) in public health units to document 9 vaccines mandated in the Immunization for Schools Pupil Act (ISPA) at the time of writing.

coverage for the 9 vaccines previously documented in IRIS (Wilson, Quach, MacDonald, Naus, Deeks, Crowcroft, Mahmud, Tran, Kwong, Tu, Johnson, et al., 2017). Panorama is still unable to link AEFI reports nor predict outbreaks in real-time. Thus, PCCs consider Panorama a failure and an issue that urgently needs addressing.

Although 5 provinces call their IIS Panorama, they function separately with very different designs (S. E. Wilson, Quach, MacDonald, Naus, Deeks, Crowcroft, Mahmud, Tran, Kwong, Tu, Johnson, et al., 2017). This means that each province has to come up with their own system to calculate vaccine coverage (Wilson, Quach, MacDonald, Naus, Deeks, Crowcroft, Mahmud, Tran, Kwong, Tu, Gilbert, et al., 2017), which leads to over-estimation or under-estimation of vaccine coverage depending on the method of calculation[68]. In Ontario, in order to generate an estimation[69] on the efficacy and safety of publicly funded vaccines, more than 5 databases need to be linked. The process is not only costly and time consuming but methodologically complex and beyond the capacity of non-research-intensive public health agencies.

To summarize, Ontario Panorama's limited functionality means that it is difficult to provide the public with substantial research evidence on the prevalence of AEFI's, likelihood of outbreaks, or the efficacy of vaccines over time in a timely manner. PCCs

[68] The federal government relies on biannual immunization surveys to estimate immunization coverage across the provinces (Wilson, Quach, MacDonald, Naus, Deeks, Crowcroft, Mahmud, Tran, Kwong, Tu, Gilbert, et al., 2017, p.1930).

[69] There are multiple immunization registries in Ontario that documents adult immunization records and coverage, including publicly funded vaccines and non-funded vaccines. However, the only meaningful way to estimate vaccine coverage and AEFIs is to link databases such as ICES holdings (e.g., hospitalization records stored in DAD, emergency department visits data stored in NACRS, and physician billing data stored in OHIP databases, et cetera) (Kwong, 2017; Wilson, Quach, MacDonald, Naus, Deeks, Crowcroft, Mahmud, Tran, Kwong, Tu, Gilbert, et al., 2017; Wilson, Quach, MacDonald, Naus, Deeks, Crowcroft, Mahmud, Tran, Kwong, Tu, Johnson, et al., 2017).

advocate that better data linkage and better ISS that generates reliable research evidence can help Ontario gain the public's trust in vaccines.

Theme 4.3. A more consistent approach across the country would reduce confusion

In Canada, each of the 13 provinces/territories have different immunization policies. Besides benchmarks for vaccine coverage recommended by NACI and the Canadian Immunization Registry Network of PHAC (Public Health Agency of Canada, 2015), no standard approach for evaluating immunization policies exists (e.g., methods for coverage assessment, operationalized measurements for calculating cost-effectiveness to introduce vaccination, methods for tracking vaccine hesitancy, etc). Each province operates separately to decide whether to introduce a vaccine and to publicly fund a vaccine or not. Similarly, provinces decide how vaccines are distributed (e.g., scheduling, delivery, and procurement), what statistical methods to use to calculate vaccine coverage, and whether immunization registries are linked with AEFI reports.

In Ontario, vaccines typically go through 3 evidence-informed evaluations and 2 policy evaluations before they are approved for public funding. (See Supplement 3 for the current policymaking process for introducing vaccines into Ontario). On average, it takes an average of 7-8 years for a vaccine to be approved and adopted by the provincial government[70]. The fragmentation of immunization policies are detrimental to the public's confidence in vaccines because different provinces have different vaccines that are publicly funded (e.g., HPV vaccine is funded and recommended for girls in some provinces, instead

[70] Derived from Martin Lavoie's presentation on "National Immunization Strategy", Western Canada Immunization Forum, March 5-6, 2014. Fantasyland Hotel, West Edmonton Mall, Alberta, Canada. Retrieved from https://www.youtube.com/watch?v=kv31FmQOnl4

of for both sexes), while some vaccines are not funded and therefore not recommended by some provinces (e.g., the MMR vaccine has been delisted in 8 provinces and replaced by the MMR-Varicella vaccine, while some provinces still have both MMR vaccine and MMR-Varicella vaccine). In addition, each province also has different vaccine schedules (e.g., the varicella vaccine is recommended to be taken at 12 months in the Province of British Columbia, 15 months in the Province of Ontario, and 4-6 years in the Province of Quebec) (Public Health Agency of Canada, 2016). Although PHAC posts immunization schedules for all provinces on their website, the incentives for following up with physicians for immunization, as well as scheduling for appointments for immunization, are entirely dependent on the motivation of parents. The above incongruences are hypothesized by some interviewees to have confused concerned parents because some vaccine recommendations seem arbitrary, which contributes to the perception that being vaccinated on-schedule is unimportant.

This incongruence also poses significant limitations for provincial immunization policymakers, because without the standardization of policy evaluation, comparing provincial outcomes across the province is difficult; it is also significantly more difficult to generate country-level statistics when it comes to immunization outcomes and AEFI reports. For instance, the federal government evaluates immunization outcomes based on measuring expenditure, analysis of programs by strategic outcomes, and the success of supplementary programs such as “up-front multi-year funding” designed to support the priorities of the Government of Canada (2014-2015 PHAC immunization report and mandate, 2015). In Ontario, the performance of Ontario’s immunization program is

evaluated based on the requirements of the Immunizations for School Pupils Act, which mandates the monitoring of 9 publicly funded vaccines for school-aged children. These evaluative outcomes coupled with an annual immunization budget report are fed into the evaluative framework of Ontario's Patients First Act, which requires all public health performance to be evaluated and reported following these 4 pillars: "access, connect, inform, protect" (MOHLTC, 2016). To contribute to additional confusion, local public health units follow the Standards and Foundations of the OPHS, and local immunization operations are guided by the Immunization Management Protocol which has been revised 4 times since its inception[71].

Discussion

Our case study results offer a set of rich insights about the challenges that governments are facing in trying to create an informed and confident public towards vaccines through the use of social media. In the following sections, we identify the contributions our case study makes to knowledge about the sources of vaccine hesitancy, potential roles for and barriers to social media use in immunization policy, the implications of these findings for policy and practice and future research in this field.

Principal findings

Our interviewees shared a diverse set of perspectives on the sources of vaccine hesitancy, the problem of vaccine misinformation on social media, and whether addressing vaccine hesitancy through social media is an issue worth addressing. These perceptions were informed by their different organizational roles (PCC vs. CCC) and levels of decision-

[71] Four different versions of the Protocol exist: 2008, 2012, 2016, 2017.

making (provincial vs. local), which in turn shape their views about whether vaccine hesitancy should (or should not) be addressed using social media. In Ontario, social media is mainly adopted as a wrap-around in the overall communications plan to inform health promotion and health protection. Numerous institutional and ideational barriers to using social media as a method of two-way communication for creating a vaccine-confident public were identified which present opportunities to evaluate policy designs that can help address the challenges of promoting vaccination under challenging conditions (e.g., budget and human resource constraints, limited policy-making capacity) and to establish mechanisms to hold government accountable when programmatic failures occur.

A novel aspect of our findings was that decisionmakers did not blame the public for the proliferation of vaccine hesitancy. Instead, they placed the onus of strengthening vaccine confidence on the flawed immunization program. This finding contrasts with other studies in the medical sciences field where the focus is on shifting the blame to those opposing vaccines or on the need to 'teach' the public about science (Hukic, 2017; Offit & Coffin, 2003). On this front, our findings identified four problem areas in the immunization program that, if addressed, can contribute towards the creation of a confident public: 1) strengthening program delivery from existing locations like clinics and schools and hospitals (e.g., "low hanging fruits"), 2) establishing reliable immunization repositories for easier data linkage, designing better information systems to track and monitor coverage and AEFIs, 3) creating more consistent immunization policies across Canada, 4) provision of research evidence on social media interventions to address vaccine hesitancy.

A second novel finding is that autonomous local initiatives formed by CCCs appear

to be partially compensating for the lack of federal and provincial guidance on social media practice. For example, the Ontario Association for Communicators in Public Health (OACPH) has become an influential resource-sharing community for social media and other strategic communication practices; similarly, the Social Media Toolkit produced by the PHU-lead Locally-Driven Collaborative Projects (LDCP) was created because there was a need for guidance in terms of social media use for public sector health organizations. We interpret these initiatives as important for two reasons: 1) to compensate for the fact that government reports and recommendations to promote vaccine hesitancy were drafted without consideration of research regarding the efficacy of social media related interventions to increase vaccine awareness, and 2) to establish precedence and experiment with social media use that can inform the drafting of laws and mandates, if any are planned to be written, on public sector social media use for immunization-related policy goals at the provincial level.

In addition to these findings, our study documented the unease of key informants, in particular, PCCs and immunization policy advisors, with the use of social media for more than information dissemination purposes. This unease was driven by the myriad challenges associated with designing and implementing conventional public health interventions for use on social media. Traditionally, immunization programs are underpinned by an evidence-informed public health framework that has an identifiable demographic upon which the design, implementation, evaluation of vaccine programs are built. Under this framework, the design of immunization programs (i.e., delivery, procurement, and the setup of injection sites) typically relies on a deep understanding of the target population. Vaccine

hesitancy proliferated by social media does not occur in localized and regional communities - the online environment allows anti-vaccine advocates as well as the vaccine hesitant to remain anonymous and geographically dispersed. A factor contributing further to this unease is current evidence from systematic reviews showing that interventions to promote vaccine acceptance, including interventions on social media, have had limited effects on vaccine acceptance (Dubé, Gagnon, et al., 2015; Moorhead et al., 2013; Sadaf, Richards, Glanz, Salmon, & Omer, 2013).

Our study findings deviate from a comparable study where social media was perceived as a manageable tool for public participation when interacting with large populations (Mossberger, Wu, & Crawford, 2013), but aligns with other work that has questioned the role of social media as a viable tool for two-way communication (Thackeray, Neiger, Burton, & Thackeray, 2013). Similarly, our findings illustrate that while the MOHLTC is striving to achieve a balance between being trustworthy and authoritative, increasing interactions with the public on social media is not perceived to enhance either of those goals. Moreover, systematic reviews suggest mass media interventions have limited effects in addressing vaccine hesitancy because the issue is highly contextual and emotional, and to date, multi-component, dialogue-based interventions such as motivational interviews at in-person settings have been shown to be more effective than other approaches (Jarrett et al., 2015).

Our study findings reinforce key messages the public administration literature that link the use of social media to how institutionalized the policy is (Bertot et al., 2012). Laws that govern equity and access, consent, and protection of privacy and personal information

on social media are different from laws that govern the same sets of parameters in an immunization policy. Terms of use in social media for government use are not enough to institutionalize the application of social media into public health promotion and protection, as such, it often acts as a barrier to implementation of evidence-informed engagement with the public via social media.

Finally, concerning communications decision-makers' views that social media can be used as sources of insight to craft strategic plans and communications tools, findings supported by our document analysis which demonstrated minimal use of public-facing websites and online activity to provide information about immunization policies suggest that policymakers have not embraced the opportunity provided by the use of social media as a governance tool for increased transparency with the public.

Strengths and limitations

This study has four key strengths. First, to our knowledge, this study represents one of a few comprehensive efforts at understanding the 'real-world' perspectives of policy and communications advisors and decisionmakers regarding the challenges and opportunities for using social media to respond to vaccine hesitancy in Canada's largest province. In highlighting the complexity of incorporating social media in governance for public health policymaking and documenting in a detailed way the reasons why social media isn't embedded into the fabric of health promotion and protection at a policy level more appropriate responses to the problem of vaccine hesitancy can be developed. This relates to the second strength of the study which is the use and triangulation of a wide range of evidentiary sources to generate a set of case study findings that can be viewed with a high

level of trustworthiness, with respect to our understanding of vaccine hesitancy and potential to address it using social media. Finally, our use of "thick description" throughout the analysis offers the opportunity for our finding to be, relatable and transferrable (Mabuza, Govender, Ogunbanjo, & Mash, 2014; Schwandt et al., 2007) to other areas of public health misinformation that are pertinent to Ontario. Finally, public health researchers interested in exploring the intersection of public health policymaking and informational discourse on social media may benefit from examining institutional information policies using principles of open government (i.e., transparent, participate, collaborate) and other social media-based government, citizens, and data models to identify barriers and facilitators of digital governance interoperability (Chun & Reyes, 2012; Chun, Shulman, Sandoval, & Hovy, 2010).

This research has some limitations. First, given the finding that social media appears to have a low level of salience to some immunization policymakers compared to other issues, this may have acted as a deterrent for some prospective interviewees who declined to participate in a study about social media use in immunization policy making, leading to a less fulsome set of perspectives on the topic. The prominence of this theme in our findings, however, suggests that this may not be a major source of concern.

Second, the pre-occupation of many of our interviewees with the weaknesses and uncertainties related to the public health system as a whole in Ontario (e.g., funding sources[72], program standards and jurisdictional responsibilities) resulted in less emphasis

[72] All PHUs are partly funded by cost-sharing programs between the municipality and the Province of Ontario for mandatory programs written in the Health Promotion and Protection Act (HPPA), funding also comes from the MOHLTC and the Ministry of Child and Youth Services (MCYS) that are program-specific (e.g., Smoke-Free Ontario, Healthy Babies Healthy Children, Infectious diseases control, etc).

being given to discussing the specific role of social media and its potential for addressing the problem of vaccine hesitancy. As a result, our findings are not as robust as we would have hoped in addressing the specific objectives of our study related to social media use, but understanding the larger policy environment within which it operates has generated critical insights that can be used to support future research and action in this area.

Implications for policy and practice

Our findings point to several recommendations for informing immunization policy aimed at using social media to address vaccine hesitancy, promote vaccine confidence and, in doing so, to strengthen public health protection and promotion.

First, immunization policymakers need to take into account the needs of PHUs in integrating social media in their daily practices. This includes the evaluation and provision of the technical capacities required to adopt social media that can be integrated into the current Protocols in the OPHS mandates for immunization program delivery. Second, given the rapid transformation taking place within the public health infrastructure in Ontario that will see the modernization of OPHS[73], guided by the Patients First Act and the integration of Public Health Units into the Local Health Integration Networks (LHINs) in 2018, there

Source: Middlesex PHU website, retrieved November 1st, 2017. URL: https://www.healthunit.com/funding-sources; Toronto Public Health operating budget submission, 2017, http://www.toronto.ca/legdocs/mmis/2016/hl/bgrd/backgroundfile-97625.pdf ; Public health funding, presentation at Association of Local Public Health Agencies (aLPHA), 2012, URL: https://www.healthunit.com/uploads/129-12-appendix-a.pdf.

[73] Under the new Standard, to be implemented in the Spring of 2018, boards of health shall "engage and establish meaningful relationships with a variety of sectors, partners, communities, priority populations, and citizens." (MOHLTC, 2018, p.22) Significant changes to scope and requirements are expected to occur, while minor changes are introduced to standards in immunization, infectious and communicable diseases (Association of Public Health, 2017). In addition, the MOHLTC attempted to address unequal distribution of funding between PHUs using a new equity-based funding formulary starting in 2015 (Ministry of Health and Long-Term Care, 2015).

is a greater demand for prioritizing listening-in and responding to the public's needs. The action items highlighted in *Public Health within LHINS: Report of the Minister's Expert Panel on Public Health*[74] (MOHLTC, 2017) provide an opportunity to allow for the integration of social media, including its appraisal as a tool for informing policymaking, into on-going discussions about the governance of the public health sector. Third, parallel to the modernization of OPHS is the Ontario Open Government[75] initiative which attempts to align with the federal government's Directive on Open Government[76]. Within this framework, there are opportunities to help government and institutional organizations overcome the challenges that come with governance on social media in the context of immunization policymaking, including privacy protection, security and data management[77], accessibility and inclusivity, and other unexpected contingencies (Bertot, Jaeger, & Hansen, 2012). These practices, informed by our findings, will increase

[74] The "Public health within an integrated health system" listed 3 action items underway in 2017: (1) modernization of OPHS that is accountable to the public, (2) collaboration between PHU and LHINs via "a Public Health Work Stream" to provide guidance on formal engagement parameters for LHINs and PHUs, and (3) expert panel on public health to advice on the structure and governance of public health for health protection and promotion for Ontario (MOHLTC Expert Panel on Public Health, 2017, p.7).

[75] Referring to the 2016 Ontario Digital Government initiative. The mandate for Digital Government Ontario is written in Sept. 2016 by Premier Kathleen Wynne to the Ministry Responsible for Digital Government, Deborah Mathews, to address priorities of the Ontario digital government initiative. The first priority is to "work with the Ministry of Health and Long-Term Care to provide better access to information and data to help people make the right choices about their health and effectively navigate the health care system […] making it easier for citizens to participate in government and for government to be more responsive to citizens". URL: https://www.ontario.ca/page/september-2016-mandate-letter-digital-government

[76] The 3rd biannual plan of the "Open Government Partnership" follows "the Directive on Open Government: open information, open data, open dialogue". The gist of the Directive is to provide citizens with access to government information, increase digital literacy of the public, to improve government transparency and accountability, such as the adoption of websites and social media accounts and establishment of provincial digital government offices. URL: https://open.canada.ca/en/content/third-biennial-plan-open-government-partnership

[77] For instance, digital repositories linking both health records and immunization records across the lifespan is needed. This will enable a more transparent and open operation of immunization programs and delivery, such as reporting AEFI's and aggregate vaccine injuries compensations.

transparency in the communication of policymaking and the uptake of public voices within the policy-making process. Fourth, policymakers could benefit from engaging communications strategists more directly in the design of effective communications plans to promote vaccine confidence informed by strong evidence, a commitment to knowledge translation with policymakers around the effectiveness of social media uptake for health promotion, and with consideration given to the values and priorities of the public, specifically those within the vaccine hesitancy constituency.

Other considerations stemming from this study are the need for PCCs and CCCS between MOHLTC, PHO, and local public health agencies to collaborate around best practices for social media use for the promotion of immunization. Public health organizations can learn from the success and failures of social media use for health campaigns from other countries and non-profit groups, such as the success of viral cancer prevention campaigns (Gough, Hunter, Ajao, Jurek, McKeown, Hong, Barrett, Ferguson, McElwee, & McCarthy, 2017), and ALS awareness campaigns (Pressgrove, McKeever, & Jang, 2018). By strengthening collaborations with non-profits[78] and organizations that with fewer financial and legal constraints regarding social media spending and practice[79], public health organizations may be able to overcome some of the resource-related barriers identified in our findings. The recommended collaborations between PHO, MOHLTC, and PHUs could be expanded to establish and evaluate and a one-stop clearing house to provide

[78] For instance, in 2016-2017, promotions for HPV vaccines was a collaborative effort between PHO, Canadian Cancer Society (CCS) Ontario branch, and PHUs willing to collaborate with CCS (Interview transcript from this research, C10).

[79] The MOHLTC invited a pro-vaccine parent-blogger to promote pro-vaccine messages on a popular parenting forum (i.e., YummyMummy.ca). Collaborations as such are highly curated and lack essential components that leverages the affordances of social media platforms.

credible, trusted, authoritative information to the public. Currently, information-sharing on social media about vaccination by each of these organizations is fragmented, requires multiple clicks, and may deter parents who have more questions (See Supplement 4 for Ontario Local Public Health Unit social media presence in 2017). Neither federal nor provincial health organizations provide vaccine information that is as easy to understand or navigate[80] such as the Centers for Disease Control in the United States. Each PHU operates vaccine promotion individually, which limits the reach and level of engagement depending on the number of followers, the use of hashtags, retweets, replies and mentions, and how timely and relevant are the information to its followers. To an extent, these duplicating and basic informational Tweets is one of the many reasons why engaging with the public on social media has been unproductive. By working together to create a clearing house, each organization would consolidate the human and financial resources allocated to promoting vaccine content.

Implications for future research

To address the barrier identified in our findings that not enough evidence supports the use of social media, researchers should continue to strive to understand the social media approaches of the anti-vaccine movement to inform the construction of government-led social media communications. Areas of focus could include learning from strategic approaches used by anti-vaccination movements such as promoting misinformation on

[80] Very little information exists on this website beyond a landing page on the importance of vaccines, vaccine schedules, and related updates. Although immunization information is maintained on the Immunize Canada website, which is a subsidiary of PHAC, each PHU and each province have their own set of vaccine information that doesn't stray further than the basics. For instance, each PHU would Tweet about the benefits of vaccines, post vaccine schedules, have a section on its webpage allocated for frequently asked questions (FAQs), and a phone number that the public can call.

image and video-based social media platforms (e.g., Pinterest and YouTube), the use of interactive techniques like webinars and Q&A sessions, the framing of anti-vaccine advocacy as non-profit parent groups, and the construction of narratives that appeal to emotions. Developing a deeper understanding of this subject matter would provide important additional evidentiary sources to inform PCC and CCC views regarding their role in relation to social media and strategies for maintaining credibility, authority, and trust. This empirical research could be complemented by theoretical research to inform the development of frameworks and indicators for measuring social media outreach and its correlation to vaccine confidence and vaccine uptake.

Conclusion

Policymakers, communications specialists, academics, and medical officers of health are integral to the immunization policymaking process. While most consider vaccine hesitancy to be a problem to be addressed, social media is not considered to be a useful tool for addressing it beyond a passive role in information dissemination. To meet the goal of a confident and informed public for immunization delivery, Ontario's immunization policies may benefit from reorienting the approach to social media to one that emphasizes listening in on the public's concerns about immunization to extract lessons from the anti-vaccine movement and their use of social media, and that supports improved communication between decisionmakers both on the policy and communications level to enhance strategies for creating a transparent, open, and accessible immunization delivery program for all.

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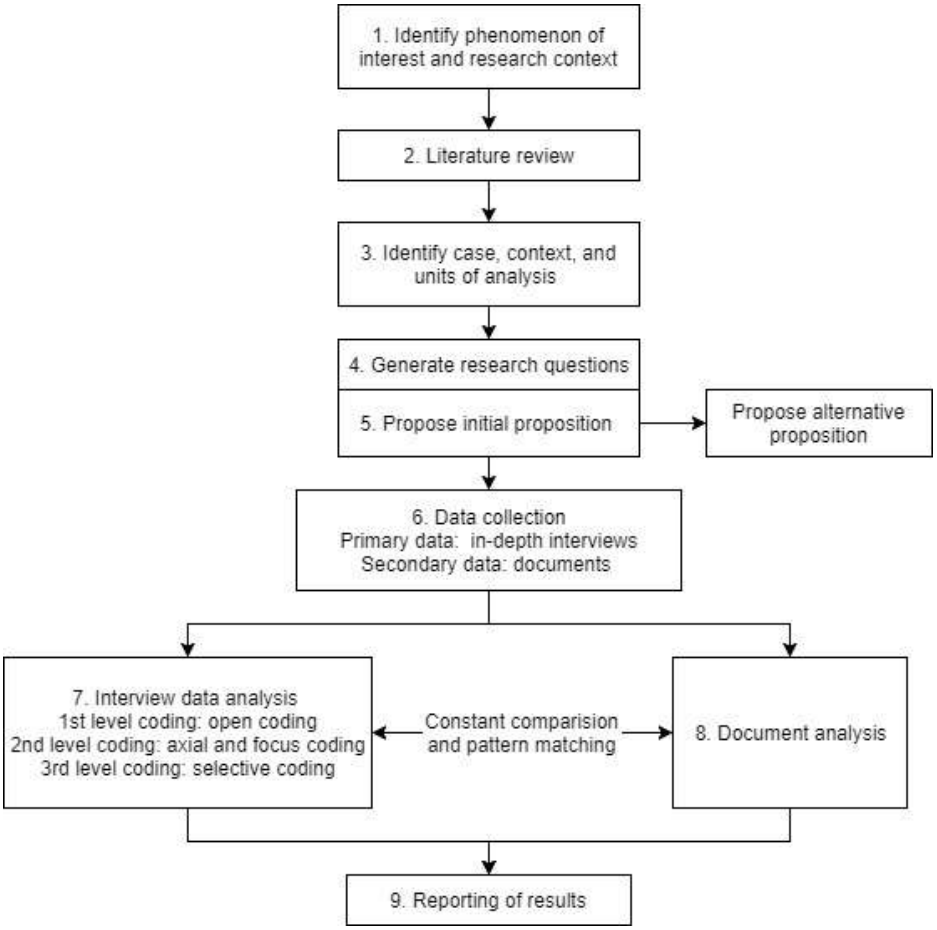
Table 1. Interviewee attributes

Participant attributes	Policy content contributors	Communication content contributors	Total
Number	14	9	23
Age			
• 31-40	2	6	8
• 41-50	5	2	7
• 51-60	4	1	5
• 60+	3	0	3
Gender			
• Female	10	5	15
• Male	4	4	8
Education level			
• MD/PHD	4	0	4
• MD	4	0	4
• PHD	3	0	3
• Master's	2	5	7
• Bachelor's	1	4	5
Years of experience in immunization			
• <5	0	4	4
• 6-20	6	5	11
• >20	8	0	8
Province			
• Ontario	10	8	18
• Other	4	1	5

Figure 1. Case study grounded theory methodology



Appendices

Appendix 1. Semi-structured interview questions

Interview questions:

1. Can you please tell me about your role at (name of institution)?
2. How are you involved in health policy making regarding vaccination?
3. Do you use social media for work-related purposes? Do people you work with use social media for work-related purposes?
4. Are you aware of anti-vaccination movement/vaccine hesitancy online? Can you tell me more about this?
5. Do dialogues on social media like anti-vaccination/vaccine hesitancy influence the way strategies for promoting vaccination are developed in your organization? If yes, please explain how this occurs?
6. Have you engaged in conversations with the online community that is promoting conflicting health information?
7. What are some experiences you have had with dealing with conflicting health information online?
8. Are there any other people (please name three) that I should contact to learn more about public health policymakers using social media in their decision-making and processes of policy promotion?
9. Is there anything you would like to add?

Appendix 2. Documents analyzed

Document selected	Document type	Date published	Data and pages analyzed
Erickson, De Wals, and Farand. An analytical framework for immunization programs in Canada. Vaccine, 23, 2470-2476.	Journal article.	November, 2004	13 categories in the framework. This framework is adapted by both federal and provincial public health for immunization program evaluation in Canada. Analysis focused on identifying whether public confidence and acceptance and the use health promotion strategies were discussed.
Immunization and vaccine-prevention: who does what at the provincial level. Webinar for MOHs and AMOHs, VPD and CD managers. Published by Public Health Ontario.	Provincial public health presentation	Jan, 2012	Clarifications of the functions and responsibilities between Public Health Ontario and the Ministry of Health and Long-Term Care. Page. 4- 12.
The Chief Public Health Officer's Report on the State of Public Health in Canada, 2013 – Immunization and vaccine-preventable diseases – Staying protected. Published online by the Government of Canada	Federal government report	November, 2013	Strategies to increase and maintain immunization coverage, contents pertaining to public confidence and strategies to increase public confidence. page. 3-8.
2014 Immunization System Review. Published by the Office of the Auditor General in Ontario.	Provincial audit report	March, 2014	Recommendations for immunization policy strengthening and Ministry's response, with a focus on its relation to public confidence on vaccines. Page. 162 – 190.
Social media toolkit for Ontario Public Health Units - a Locally Driven Collaborative Project (LDCP). Published by Public Health Ontario.	Local public health publication	February, 2014	Recommendations, rationale, purpose, and evaluation of the use of social media in Ontario for health promotion. Entire document, including appendices.
Ontario's Publicly Funded Immunization System: Building on Today's Strengths, innovating for the future. Report of the advisory committee for Ontario's Immunization System Review. Published by the Ministry of Health and Long-	Provincial government report	March, 2014	Core essentials for a successful immunization delivery program (p. 12 – 39)

Term Care.			
Measles outbreak 2015 and Ontario's Immunization system	Local public health staff report	June, 2015	Medical Officer of Health recommendations to reduce the spread of measles. Page. 1-9.
Immunization 2020: Modernizing Ontario's Publicly Funded Immunization Program. Published by the Ministry of Health and Long-Term Care.	Provincial government report	December, 2015	Goals of Immunization 2020 in conjunction with the release of "Patient First", Strategic Framework of Immunization 2020, Action plan of Immunization 2020. Drawing particular emphasis on looking at goals, strategies, and action plans that includes public confidence in vaccines.
Estimates Briefing Book, 2016-2017. Prepared by the Ministry of Health and Long-Term Care.	Government budget briefing	February, 2016	Ministry of Health estimate briefing is broken down to four parts: "access, connect, inform, protect". All immunization-related expenditures, particularly areas that pertain to "informing" the public are analyzed. Page. 48-49.
Immunization Management Protocol 2016. Published by the Population and Public Health Division, Ministry of Health and Long-Term Care.	Provincial government protocol	May, 2016	Immunization protocols in reference to the Ontario Public Health Standards, Child Care and Early Years act, and Immunization of School Pupils Act. Page. 1-9.
Evaluation of Immunization and Respiratory Infectious Disease Activities at the Public Health Agency of Canada, 2011-2012 to 2015-2015. Prepared by the Office of Audit and Evaluation.	Federal report	October, 2016	Evaluations related to the performance of immunization programs, in particular, Recommendation #3 and budgeting for recommendation #3. Page. 8, 11.
2016 Annual Report for the Ministry of Health and Long-Term Care. Prepared by the Office of the Auditor General of Ontario.	Provincial government report	November, 2016	This report is a follow-up on the 2014 audit report. Areas related to increasing public confidence and immunization coverage were analyzed.
Canada's Provincial and Territorial Routine (and catch-up) Vaccination Programs for infants and children. Published by the Public Health Agency of Canada.	Chart	December, 2016	Overview of funded and publicly available vaccines, as well as recommended schedule for vaccination in Ontario in comparison to other provinces were analyzed. Page. 1.
Ontario Public Health Modernization, prepared by	Technical briefing	February,	OPHS will be phasing out in 2018, changes in

the Association of Public Health (alpha)		2017	the OPHS standard compared to immunization standards based on the current OPHS standards are analyzed.
Public Health Agency of Canada, 2017-18, Departmental Plan	Federal government plan	February, 2017	PHAC plans pertaining to immunization were analyzed in conjunction with the 2016 "Evaluation of Immunization and Respiratory Infectious Disease Activities at the Public Health Agency of Canada".
Immunization Management Protocol 2017. Published by the Population and Public Health Division, Ministry of Health and Long-Term Care.	Provincial government protocol	September, 2017	Differences compared to the 2016 Immunization Management Protocol were analyzed.

Appendix 3. List of Interviewees by jurisdiction, position and organizational affiliation

Code	Jurisdiction (e.g., Ontario, BC, etc.)	Role/position (e.g., policy advisor, policy decision maker, communications advisor, communications decision maker)	Organizational affiliations (primary and secondary) (level, type and role)
P1	Ontario	Policy advisor	Academic; also involved in federal and provincial government, and local advisory committees and local agencies.
P2	Ontario	Policy advisor and decisionmaker	Local agency; academic; also involved in international, federal, provincial, and local governmental agencies and advisory groups.
P3	Ontario	Policy advisor	Provincial government; academic, also involved in international, federal, provincial, and local governmental agencies and advisory groups.
P4	Ontario	Policy advisor	Provincial non-governmental association and local agencies.
P5	Ontario	Policy advisor and decision maker	Local agency; academic; also involved in provincial and local governmental agencies and advisory groups.
P6	Nova Scotia	Policy decision maker and advisor	Local agency; academic; also involved in international, federal, provincial and local governmental agencies and advisory groups.
P7	Ontario	Policy decision maker	Local health system; academic, also involved in federal, provincial, and local government agencies and advisory groups and federal/provincial/local non-governmental associations.
P8	Ontario	Policy advisor	Provincial advisory group; academic, also involved in provincial, and local government agencies and advisory groups.
P9	British Columbia	Policy advisor	Academic; provincial advisory group, also involved in provincial

			and local government agencies and advisory groups.
P10	Ontario	Policy advisor	Local non-governmental agency; academic, also involved in provincial and local governmental agencies and advisory groups.
P11	Nova Scotia	Policy advisor	Academic; provincial advisory group, also involved in provincial and local government and non-government agencies and advisory groups.
P12	Quebec	Policy decision maker and advisor	Provincial government agencies; academic, also involved in federal and local government agencies and advisory groups.
C1	Ontario	Communications decision maker	Local health system, local agency
C2	Ontario	Communications decision maker	Provincial governmental agency
C3	Ontario	Communications decision maker	Provincial agency and provincial non-governmental association
C4	Ontario	Communications decision maker	Provincial government
C5	Ontario	Communications decision maker	Provincial government
C6	Ontario	Communications decision maker	Local agency
C7	Ontario	Communications decision maker	Local agency and provincial non-governmental association
C8	Ontario	Communications decision maker	Local agency
C9	Ontario	Communications decision maker	Local agency and provincial non-governmental association
C10	British Columbia	Communications decision maker	Provincial government and provincial advisory groups
C11	Ontario	Communications decision maker	National non-governmental association and provincial non-governmental association and local agency

Supplement 1. Laws related to government use of social media in Canada

Level	Purpose for the establishment of laws related to government use of social media in Canada					
	Policy on information management	Access and social inclusion	Health professional conduct	Protection of information and privacy	Smart Systems for Governance	Consent and Terms of Use
Federal	Policy on Information Management[81], 2007.	Canadian Human Rights Act[82]	Nurses' social media use[83], Canadian Nurse Protective Society, 2010	Personal Information Protection and Electronics Documents Act (PIPEDA)[84], Office of the Privacy Commissioner of Canada, 2000		
	Directive on Open Government[85]: "open information, open data, open dialogue", 2014.		Regulated Health Professions Act (RHPA)[86], 1991	Canada Digital Privacy Act[87], 2015		
	Mandate letters to Ministers[88], Prime Minister of					

[81] URL: http://www.tbs-sct.gc.ca/pol/doc-eng.aspx?id=12742

[82] Extend the laws in Canada to give effect, within the purview of matters coming within the legislative authority of Parliament to the principle that all individuals should have an opportunity equal with other individuals to make for themselves the lives that they are able and wish to have and to have their needs accommodated... without being hindered in or prevented from doing so by discriminatory practices based on race, national or ethnic origin, colour, religion, age, gender, sexual orientation, marital status, family status, disability or conviction for an offence for which a pardon has been granted" (Canadian Human Rights Act).

[83] There is no official name for this document, retrieved from CNPS website. URL: http://www.cnps.ca/upload-files/pdf_english/social_media.pdf

[84] PIPEDA governs conduct for private-sector organizations, including non-profit organizations. URL: https://www.priv.gc.ca/en/privacy-topics/privacy-laws-in-canada/the-personal-information-protection-and-electronic-documents-act-pipeda/r_o_p/

[85] Canada's "Open by Default" policy, providing clear and mandatory requirements to departments to ensure that Canadians gain access the most government information and data possible. URL: http://www.tbs-sct.gc.ca/pol/doc-eng.aspx?id=28108 .

[86] http://www.health.gov.on.ca/en/pro/programs/hhrsd/about/rhpa.aspx

[87] This Law amends the Personal Information Protection and Electronic Documents Act (PIPEDA), URL: http://laws-lois.justice.gc.ca/eng/annualstatutes/2015_32/page-1.html

[88] The Prime Minister's mandate letters are available to the public as part of the Open Government initiative, October, 2017. The Prime Minister's

	Canada, 2017					
Provincial	Mandate letter of premier's instructions to ministers on priorities[89], 2016	Accessibility for Ontarians with Disabilities Act[90], 2005	Social Media appropriate use by physicians[91], College of physicians and surgeons in Ontario	Personal Health Information Protection Act[92]	E-Health Act[93], MOHLTC, 2012	Social media terms of use[94], Government of Ontario, 2017
				Freedom of Information and Privacy Manual[95], Government of Ontario, 2016		Ontario public service social media guidelines[96], Government of Ontario, 2017

Letter to the Minister of Health, discussing the commitment to an open, transparent government can be retrieved from the URL: https://pm.gc.ca/eng/minister-health-mandate-letter

[89] URL: https://www.ontario.ca/page/september-2016-mandate-letter-digital-government#section-1

[90] "Communication supports" may include, but are not limited to, captioning, alternative and augmentative communication supports, plain language, sign language and other supports that facilitate effective communications.

[91] URL: http://www.cpso.on.ca/Policies-Publications/Positions-Initiatives/Social-Media-Appropriate-Use-by-Physicians

[92] URL: https://www.ontario.ca/laws/statute/04p03

[93] The E-Health Act in Ontario details the objectives of eHealth Ontario to provide digital health services to support the "planning, management, and delivery of health care in Ontario", to "develop operational policy for the provision of digital health technology services, and to "protect the privacy of individuals whose personal information or personal health information is collected, transmitted, stored, or exchanged by and through the Agency" in accordance with FIPPA and PHIPA. URL: https://www.ontario.ca/laws/regulation/020043

[94] URL: https://www.ontario.ca/page/social-media-terms-use

[95] The manual sets guidelines about the administrative responsibilities to fulfill the Municipal Freedom of Information and Protection Privacy Act (MFIPPA) and the Freedom of Information and Protection of Privacy Act (FIPPA), https://www.ontario.ca/document/freedom-information-and-privacy-manual/administration-act

[96] URL: https://www.ontario.ca/page/ontario-public-service-social-media-guidelines

Supplement 2. Laws and Standards governing immunization program delivery (F/P/Local)

1. Public Health agency of Canada Act (created in 2006; amended in 2015)	
Level of order	Federal legislation, Order of the Queen's Privy Council
Followed by	Public Health Agency of Canada, Reports to the Ministry of Health
Purpose in relation to immunization policies	The establishment of the Public Health Agency of Canada oversees disease control and protection, health safety (including immunization and vaccine), and the production of research and statistics on a federal level. The Centre for Immunization and Respiratory Infectious Diseases (CIRID) is responsible for aligning F/T/P priorities to strengthen immunization efforts under the Department of Health Act (1996) in conjunction with the Public Health Agency of Canada Act of 2006. Facing the public, CIRID oversees the production of the Immunization Schedule Tool[97], and core publications like the Canadian Immunization Guide[98] and Immunization competencies for Health Professionals[99].
2. National Immunization Strategy (created in 2003, started in 2004)	
Level of order	Federal Strategy established by F/T/P Deputy Ministers of Health in 2003.
Followed by	Recommended to be followed by F/T/P's
Purpose in relation to immunization policies	The NIS was created based on the "Final Report: National Immunization Strategy"[100] in a response to the concerns of the growing cost of new vaccines, security of supply, public attitude, vaccine safety, and fear of outbreaks. From 2003 to 2013, the effort lead to the establishment of the NACI committee for credible vaccine reviews and guidance for new vaccines, and the support of knowledge translation for evidence-based decision for vaccine assessment, program design, risk mitigation, and crisis response. It also reportedly strengthened core competencies for efficient and effective program design and delivery, more robust AEFI reports, lower vaccine prices through FPT bulk purchasing, more reliable supply, enhanced ability to trace vaccine stocks, and improved capacity to coordinate recalls[101]. Created by the Communicable and Infectious Diseases Steering

[97] The PHAC Immunization Schedule Tool. URL: http://www.healthycanadians.gc.ca/apps/schedule-calendrier/index-eng.php

[98] Consisting of 54 chapters, the guide is only available online and users are able to received updates via subscription online when changes are being made. URL: https://www.canada.ca/en/public-health/services/canadian-immunization-guide.html

[99] The Immunization competencies for health professionals' guidebook, provided by the Professional Education Working Group of the Canadian Immunization Committee (CIC), approved by the Communicable Disease Control Expert Group and the Pan-Canadian Public Health Network, published by PHAC CIRID, 2008. URL: http://www.phac-aspc.gc.ca/im/pdf/ichp-cips-eng.pdf

[100] Retrieved on August 3rd, 2017. URL: https://www.canada.ca/en/public-health/services/reports-publications/national-immunization-strategy-final-report-2003.html

[101] At the time of writing (August, 2017), the NIS website was broken, I was unable to find the interim report on NIS. The only source that I was able to draw evidence from is a YouTube video recorded by the Government of Alberta. Martin Lavoie, then co-chair of the National Immunization Strategy, gave a presentation on the current status of the NIS in 2014 during the Western Canada Immunization Forum in Alberta, Canada. Retrieved from https://www.youtube.com/watch?v=kv31FmQOnl4. There is no online information available as to who the NIS is composed of, how often they meet, how are they selected, etc. There were significant overlaps of names that were mentioned in the video with the Pan-Canadian Public Health Network (PHN) Communicable and infectious Disease Steering Committee (PHN-CID SC) members. It was mentioned in the video that the NIS Task Group

	Committee (CID SC) of the FPT-Pan-Canadian Public Health Network (PHN)[102], The NIS Task Group (NISTaG) is mandated to conduct reviews of the NIS, assess current strategies, and generate reports. In "Future direction for immunization in Canada"[103] submitted in 2014, its 10 focuses were to provide overarching direction and coordination, vaccine guidance and coordinated schedule and program; vaccine innovation and development; programmatic research and evaluation; surveillance, outbreak and adverse event response, immunization scheduling, public and professional engagement and education; security of vaccine supply; no-fault vaccine injury compensation.
3. Immunization of School Pupils Act (ISPA) (established 1977, amended 2017) in conjunction with the Protecting Patients Act (2017)	
Level of order	Provincial
Followed by	Boards of health in Ontario, reports to MOHLTC
Purpose in relation to immunization policies	The Act requires parents of children attending primary or secondary school provide their local medical officer of health with proof of their child's immunization against 6 designated diseases. In 2014/2015, 3 vaccines (Meningococcal, pertussis, varicella) are added into the requirements for attending school. Public health units assess immunization coverage and contact parents of students for whom they do not have complete immunization records. Exemptions from immunization requirements are allowed for medical reasons (i.e., prior immunity or medical contraindication) or based on an affidavit of conscience or religious belief. Children for whom the public health unit does not have required immunization records or a valid exemption may be temporarily suspended from school until the required records are provided.
4. Child Care and Early Years Act (established 2014, amended 2017; formerly Daily Nurses Act, which was spent in 2015)	
Level of order	Provincial
Followed by	Followed by the Ministry of Education, reports to the Government of Ontario
Purpose in relation to immunization policies	In Immunization 35, "(1) Every licensee shall ensure that before a child who is not in attendance at a school or private school, within the meaning of the *Education Act*, is admitted to a child care centre it operates or to premises where it oversees the provision of home child care, and from time to time thereafter, the child is immunized as recommended by the local medical officer of health. O. Reg. 126/16, s. 24 (1). (2) Subsection (1) does not apply where a parent of the child objects to the immunization on the ground that the immunization conflicts with the sincerely held convictions of the parent's religion or conscience or a legally qualified medical practitioner gives medical reasons to the licensee as to why the child should not be immunized. O. Reg. 126/16, s. 24 (2). (3) Objections and medical reasons under subsection (2) shall be submitted in a form approved by the Minister. O. Reg. 126/16, s. 24 (3). (4) An exemption under subsection (2) that was made before August 29, 2016 shall expire on September 1, 2017 unless a new objection or medical reasons are submitted in a form approved by the Minister before that date. O. Reg. 126/16, s. 24 (3)."
5. Protecting Patients Act (2017)	

was composed of 10 members and 2 co-chairs (Martin Lavoie, provincial territorial co-chair; John Spikof, federal co-chair), and that they have met 4 times in 2 years, conducted 25 teleconferences, including outreach to experts, stakeholders, industry, and academia. Periodic briefings with F/P/T partners, and a 2-part final report provided to CID-SC in 2013, which is not available anywhere online or to the public.

[102] Names and positions of PHN-CID SC can be found on the PHN website. URL: http://www.phn-rsp.ca/cidsc-cdmti-eng.php

[103] Not available online, this information was only available through the YouTube video. URL: https://www.youtube.com/watch?v=kv31FmQOnl4.

Level of order	Royal Assent received
Followed by	Medical Officers of Health in 36 Public Health Units
Purpose	In 2017, bill 87 of the Protecting Patients Act passed to require parents to receive an education session from the Medical Officers of Health to receive a medical exemption or exemptions based on religious beliefs.
6. Health Promotion and Protection Act (HPPA)	
Level of order	Provincial
Followed by	Boards of health in Ontario
Purpose in relation to immunization policies	The HPPA includes immunization as one of its mandatory health services, areas related to immunization include the control of infectious diseases and reportable diseases; health promotion and health protection and disease and injury prevention, the collection and analysis of epidemiological data. Under Section 62 of the HPPA, each board of health is required to appoint a full-time medical officer of health. A medical officer of health: (1) Is responsible to the board for the management of the public health programs and services; (2) Directs staff of the board of health/public health staff (who are responsible to the medical officer of health) if their duties relate to the delivery of public health programs or services; (3) Has authority that is limited to the health unit served by the board of health; and (4) Is entitled to attend each meeting of the board and its committees (except as relates to the performance and remuneration of the medical officer of health). The MOH will oversee immunization coverage and report to PHO in the event of an outbreak, as well as attend routine teleconferences and meetings around immunization.
7. Health Care Consent Act (HCCA), 1996	
Level of order	Provincial
Followed by	Boards of health in Ontario, PHO, MOHLTC
Purpose in relation to immunization policies	This Act decides how a person can consent to immunization. According to HCCA, any health procedure, including immunization, has to be done with the consent of the student, in the case that the student doesn't want to get vaccinated and the parent does, then the student's decision holds; if the students wants to and the parent doesn't, then the nurse will determine if the student is capable of providing consent and act according to the students' wishes if he/she is capable of consent. There is no age limit for consent, so anyone that is in school can act of their own behalf, as long as (1) the person understands the information that is relevant to making decision about the treatment, and (2) appreciate the likely consequences of his/her decision or lack of decision.
8. Enhanced Surveillance Directives (ESD)	
Level of order	Provincial
Followed by	PHO
Purpose	PHO is responsible for the surveillance of outbreaks, it also publishes monthly infectious diseases surveillance reports similar to CDC's Morbidity and Mortality Weekly.
9. Ontario Public Health Standards (2008) (2 standards and 4 protocols[104] relate to immunization)	

[104] Protocols are program and topic specific documents that provide directions on how Boards of Health must operationalize specific requirement(s) identified within the OPHS. The Protocols and Programs are important mechanisms by which greater standardization is achieved in the province-wide

Level of order	Provincial
Followed by	Boards of health in Ontario
Purpose in relation to immunization policies	The OPHS is published pursuant to Section 7 of the Health Protection and Promotion Act, R.S.O. 1990, c. H.7., this Standard has 13 sub-standards that underlies PHUs responsibilities for Health promotion and policy development, disease prevention, and health protection. It is published by the Minister of Health and Long-Term Care under the authority of the Health Protection and Promotion Act (HPPA) to specify the mandatory health programs and services provided by boards of health. The boards of health in local PHUs are responsible for the "assessment, planning, delivery, management, and evaluation" of a variety of programs. Many standards are supported by specific protocols. (Act > Standard > Requirements following Protocol) Specifically, there are two areas under the "Infectious Diseases Program Standard" that is applicable to immunization: "infectious diseases prevention and control program standard", and the "vaccine preventable diseases program standard". PHUs adhere to the (1) Immunization Management Protocol, and the (2) Infectious Diseases Protocol. For the Surveillance of these data, PHUs adhere to the (3) Infectious Diseases protocol, and the (4) Population health assessment protocol.
10. Standards for Public Health Programs and Services (SPHPS) (2017)[105] to replace OPHS	
Level of order	Provincial
Followed by	Boards of health in Ontario
Purpose in relation to immunization policies	On February 17, 2017, the MOHLTC released the SPHPS Consultation Document. The SPHPS is published pursuant to Section 7 of the Health Protection and Promotion Act, R.S.O. 1990, c. H.7., and specifies minimum requirements for public health programs and services in Ontario. This Standard has 12 sub-standards and focus on program outcomes. At this time, the MOHLTC has advised that implementation of the revised standards and protocols, the latter are yet to be developed, but will expect commence January 2018.
11. Health Equity Impact Assessment (HEIA)	
Level of order	Provincial
Followed by	Boards of health in Ontario, PHO, MOHLTC
Purpose in relation to immunization policies	The HEIA needs to be used with OPHS foundational standard and PHAS, to support policy and program planning – the HEIA integrates equity considerations into the development and evaluation of policies, programs, or initiatives by systematically identifying priority populations and potentially unintended health impacts, as well as develop monitoring measures for equity. In the form of immunization, this program will look at (1) the scope, (2) potential impacts, (3) mitigation (reduce negative impacts), and (4) monitor equity, and (5) dissemination of these results to address equity to a wider population or apply to other

implementation of public health programs.

[105] The soon-to-retire OPHS include societal and board of health outcomes; the modernized Standards include population health outcomes, as articulated in the "policy framework for public health programs and services" and program outcomes. To simplify, societal outcomes are changed to population health outcomes. "Board of Health outcomes" are changed to "program outcomes", which refers to representing the results achieved through Public Health programs and services delivery.

	projects. Health equity will be a much more important focus as revisions to OPHS is underway.
12. Population Health Assessment and Surveillance (PHAS) protocol (2016)	
Level of order	Provincial
Followed by	Boards of health in Ontario
Purpose in relation to immunization policies	Requirements for local boards of health to conduct population health assessment, surveillance, research, knowledge exchange and program evaluation are embedded in the OPHS Foundational Standard and the Population Health Assessment and Surveillance (PHAS) Protocol, in order to contribute to the public health knowledge base and ultimately improve public health programs and services, including those aimed at reducing health inequities (see HEIA). The board of health shall collect or access the following types of population data, including: iv) preventative health practices including immunization, oral health, physical activity, healthy eating, healthy weights, road and off-road safety, cancer screening, sexual practices, breast-feeding, preconception health, healthy pregnancies, preparations for parenting, positive parenting, and health family dynamics. And ix) other relevant data and information regarding: attitudes, awareness, and knowledge; public health policies, programs and services, the legal and political environment, stakeholder perspectives, and program evaluation. And finally, for VPD standard, it is the Requirement #2 that: The board of health shall conduct epidemiological analysis of surveillance data, including monitoring of trends over time, emerging trends, and priority populations, in accordance with the Infectious Diseases Protocol, 2008 (or as current) and the Population Health Assessment and Surveillance Protocol, 2008 (or as current).
13. Infectious Diseases Protocol (2018)	
Level of order	Provincial
Followed by	Boards of health in Ontario
Purpose in relation to immunization policies	The PHU is responsible for (1) reporting infectious diseases[106], forwarding reports to the ministry or PHO, with respect to (2) immunization coverage in accordance with the "Immunization Management Protocol, 2017". These reports will be made using Panorama or any other method specified by the Ministry. Finally, "A report made to the ministry or, as specified by the ministry, to PHO using iPHIS, Panorama or any other method specified by the ministry shall comply with *Enhanced Surveillance Directives (ESD)* that are active at the time that the report is being made." The PHU is also responsible for (3) policy planning after the interpretation and application of surveillance data, "to plan evidence-based public health policies, programs and services to prevent and control infectious diseases in the community and in high-risk settings"; and evaluate the above policies, programs. And "outbreak notification and communication of outbreak information to community partners with an identified role in the diagnosis and treatment of infectious diseases, and in the control and management of infectious diseases outbreaks, including but not limited to physician offices, hospitals, the public health laboratories of PHO, and facilities and institutions such as child care centres (as defined in the Child Care and Early Years Act) and long-term care homes"
14. Institutional/facility outbreak prevention and control protocol (2016)	
Level of order	Provincial
Followed by	Boards of health in Ontario

[106] Reportable events include those that may be related to the administration of an immunizing agent as defined in the HPPA (p.8)."

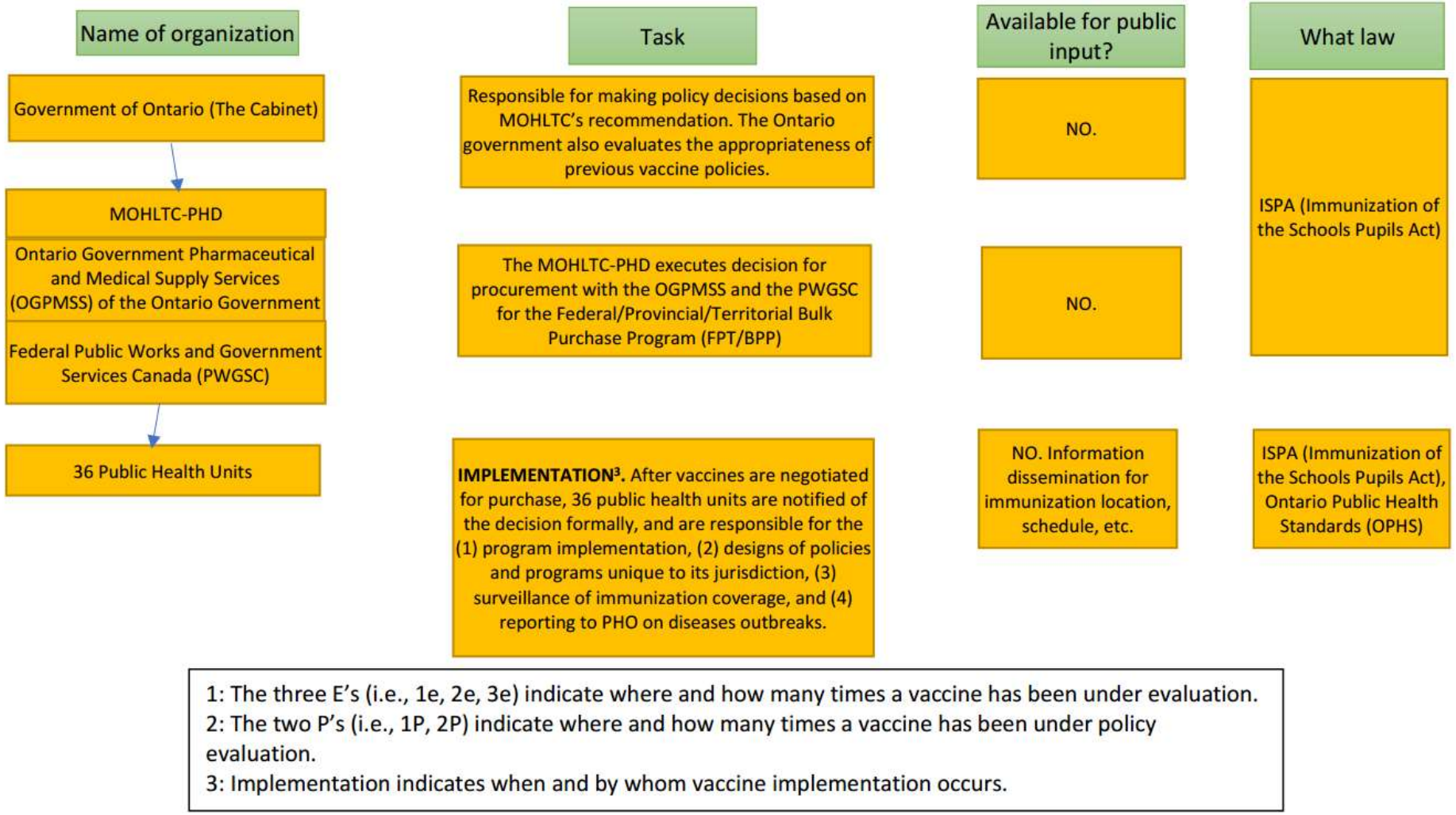
Purpose in relation to immunization policies	Protocol under OPHS: Including hospitals, long-term care homes, child care centres and other institutional/facility settings. Does not include Retirement Homes – The Ministry of Health and Long-Term Care does not regulate Retirement Homes, as a Retirement Home is not expressly listed as an "institution" under the HPPA. To determine if the board of health's activities for preventing and managing outbreaks in this protocol may be applied in Retirement Homes, the Ontario Seniors' Secretariat (OSS) should be consulted or, where applicable, legal counsel. Under the Infectious Diseases Protocol, 2008 (or as current) boards of health shall provide public health investigation and management of confirmed or suspected local outbreaks of public health importance, which may include the management of outbreaks in Retirement Homes. Outbreak updated to iPHIS by boards of health.
15. Immunization management protocol (2017)	
Level of order	Provincial, published by Public Health Ontario
Followed by	Public Health Units, reports to PHO
Purpose in relation to immunization policies	PHUs need to conduct and report immunization coverage rates with respect to designated diseases for school pupils and recommended vaccines for children attending a child care centre, once a year, or more often as required, to the ministry, or as specified by the ministry to the Public Health Ontario
16. Guidance for Toronto's Child Care Centres, 2016, "Infection Prevention and Control in Child Care Centres"[107]	
Level of order	Local, Toronto Public Health
Followed by	Child care centres
	Individual child care centres have to create their own documents of managing outbreaks: "All child care centres must develop and maintain written policies and procedures in preparation for responding to infectious disease outbreaks, including but not limited to gastroenteritis outbreaks. Toronto Public Health will review these written policies and procedures on an annual basis during your routine inspection[108]."

[107] URL: https://goo.gl/UfY8tv

[108] "Two public health staff will work with the day care centre in the event of an outbreak. A Public Health Inspector from Healthy Environments will assist you with your environmental control measures for gastrointestinal illness outbreaks […]. A Communicable Disease Investigator from Control of Infectious Diseases & Infection Control (CID/IC) will assist in case management for gastrointestinal and respiratory illness outbreaks (e.g. review line lists, provide exclusion letters, facilitate stool kit submission to the Ontario Public Health Lab and declare the outbreak over)" (ibid, p.28).

Supplement 3. The policymaking process for introducing vaccines in Ontario, from vaccine approval to vaccination

Supplement 3 (continued)



1: The three E's (i.e., 1e, 2e, 3e) indicate where and how many times a vaccine has been under evaluation.
2: The two P's (i.e., 1P, 2P) indicate where and how many times a vaccine has been under policy evaluation.
3: Implementation indicates when and by whom vaccine implementation occurs.

Supplement 4. Ontario Local Public Health Unit social media presence (compiled in August, 2017)

LHINS*	Public Health Units**	Website	Facebook	Twitter	Others (e.g., Instagram, LinkedIn, Pinterest)
Erie St. Clair	Chatham-Kent (Chatham)	http://ckphu.com/	https://www.facebook.com/CKPublicHealth (2019)	https://twitter.com/CKPublicHealth (1133)	https://www.youtube.com/user/ckphu (454) https://www.pinterest.com/ckpublichealth/ (342)
	Lambton (Point Edward)	www.lambtonhealth.on.ca	https://www.facebook.com/lambtonpublichealth/ (475)	https://twitter.com/lambton_ph/ (22)	https://www.youtube.com/channel/UCMFFyWPd6Ii4-arU3iviYHA (17)
	Windsor-Essex County (Windsor)	www.wechu.org	https://www.facebook.com/TheWECHU/ (8920)	https://twitter.com/thewechu (1643)	https://www.youtube.com/user/wechealthunit (0) lots of videos but no subscribers https://www.linkedin.com/company/9299577/ (227)
South West	Huron County (Clinton)	www.huronhealthunit.ca	https://www.facebook.com/HuronCountyHealthUnit/ (895)	https://twitter.com/huronbeachinfo (1371)	
	Middlesex-London (London)**	https://www.healthunit.com/	https://www.facebook.com/middlesex.london.health.unit/ (6647)	https://twitter.com/MLHealthUnit (10.1k)	https://www.youtube.com/user/mlhealthunit (627) https://ca.linkedin.com/company/middlesex-london-health-unit
	Grey Bruce (Owen Sound)	www.publichealthgreybruce.on.ca/	https://www.facebook.com/greybrucepublichealth (1842)	https://twitter.com/GBPublicHealth (1908)	https://www.youtube.com/user/GreyBruceHealthUnit (864) https://www.linkedin.com/company/10339200/ (104)
	Haldimand-Norfolk	www.hnhu.org	https://www.facebook.com/hnhealthunit/ (1462)	https://twitter.com/HNHealthUnit (519)	https://www.instagram.com/hnhealthunit/ (85) https://www.youtube.com/user/hnhucommunications (43)
	Elgin-St. Thomas	https://www.elginhealth.on.ca/	https://www.facebook.com/ESTPH (3175)	https://twitter.com/ElginHealth (1323)	https://twitter.com/ElginHealth (147) https://www.youtube.com/user/ESTPH1 (5)
	Perth district	www.pdhu.on.ca	https://www.facebook.com/pdhealthunit/ (1046)	https://twitter.com/PDHealthUnit (1138)	
	Oxford country public health	www.oxfordcounty.ca/health	http://www.oxfordcounty.ca/health (1528)	https://twitter.com/oxfordcounty (3633)	https://www.youtube.com/user/oxfordcountyontario (63)
For all Southwest PHU	Southwest Health Line	http://www.southwesthealthline.ca/			
Waterloo Wellington	Fergus (Wellington-	https://www.wdgpublichealth.ca	https://www.facebook.com/WDGPublicHealth/ (382)	https://twitter.com/wdgpublichealth (3325)	https://www.linkedin.com/company/1040046/ (557)

	Dufferin-Guelph)	/			https://www.youtube.com/c/WDGPublicHealth (34)
	Waterloo (Region of Waterloo public health and emergency services)	http://chd.region.waterloo.on.ca/en/index.asp	https://www.facebook.com/rowpublichealth (1018)	https://twitter.com/ROWPublicHealth (3739)	N/A
Hamilton Niagara Haldimand Brant	Brantford	www.bchu.org/	https://www.facebook.com/branthealthunit (411)	https://twitter.com/branthealthunit (1347)	N/A
	Hamilton (*Hamilton Public Health Services)	www.hamilton.ca/publichealth	https://www.facebook.com/HealthyFamiliesHamilton/ (6024)	https://twitter.com/cityofhamilton (58.8k)	https://www.instagram.com/cityofhamilton/ (34)
	Oakville (Halton region health department)	www.halton.ca/living_in_halton/public_health/	https://www.facebook.com/RegionofHalton/ (2743)	https://twitter.com/RegionofHalton (8368)	https://www.youtube.com/channel/UCWauZbB02FGtaiNXuw1uw-w (56)
	Simcoe (Haldimand-Norfolk)	http://www.hnhu.org/	https://www.facebook.com/hnhealthunit/ (1462)	https://twitter.com/HNHealthUnit (519)	https://www.youtube.com/user/hnhucommunications (43) https://www.instagram.com/hnhealthunit/ (85)
	Thorold (*Niagara region public health department)	http://www.niagararegion.ca/living/health_wellness/default.aspx	https://www.facebook.com/niagararegion (12,429)	https://twitter.com/niagararegion (17.1k)	https://www.youtube.com/user/NiagaraRegionCA (308)
Central West	Fergus (2)	See Fergus			
	Newmarket (*York region public health services)	http://www.york.ca/wps/portal/yorkhome/health	https://www.facebook.com/YorkRegionGovt (15,619)	https://twitter.com/YorkRegionGovt (18.1k)	http://www.youtube.com/YorkRegionGovt (602)
	Toronto	www.toronto.ca/health	https://www.facebook.com/torontopublichealth/ (13414)	https://twitter.com/TOPublicHealth (29.4k)	https://www.pinterest.com/topublichealth/ (723) https://www.youtube.com/user/TPHCommunications (206)
Mississauga and Halton *indicated combined municipal services	Mississauga (*Peel public health)	https://www.peelregion.ca/health/	https://www.facebook.com/parentinginpeel/ (15449) Parenting page,	https://twitter.com/regionofpeel?lang=en (18.4k)	https://www.youtube.com/user/theregionofpeel (1209)
	Oakville (Halton) (2)	See Oakville			
	Toronto (2)	See Toronto			

Toronto Central	Toronto (3)				
Central	Toronto (4)				
	Newmarket (York) (2)				
Central East	Peterborough	http://www.peterboroughpublichealth.ca/	https://www.facebook.com/Ptbohealth (775)	https://twitter.com/Ptbohealth (1924)	https://www.youtube.com/user/PCCHUHealthUnit (7)
	Port Hope (Haliburton,Kawartha, Pine ridge district health unit)	http://www.hkpr.on.ca/	https://www.facebook.com/HKPRDHU/ (350)	https://twitter.com/HKPRDHU (1204)	https://www.youtube.com/user/HKPRDHU (317)
	Toronto (5)	See Toronto			
	Durham*	https://www.youtube.com/user/PCCHUHealthUnit	https://www.facebook.com/DurhamHealthyFamilies/	https://twitter.com/DurhamHealth (2696)	https://www.youtube.com/channel/UCigjHXPeVAUBRApMwyybm5w (48)
South East	Belleville (Hastings and Prince Edward Counties)	www.hpechu.on.ca	https://www.facebook.com/hpepublichealth/ (4468)	https://twitter.com/HPEPublicHealth (871)	https://www.youtube.com/channel/UCikA8QusuOGTQ-WJSuDWCiw (16)
	Brockville (Leeds, Grenville, and Lanark District)	www.healthunit.org	https://www.facebook.com/LGLHealthUnit/ (1191)	https://twitter.com/lglhealthunit?lang=en (283)	https://www.youtube.com/user/LGLHealthUnit (12)
	Kingston (Kingston, Frontenac, Lennox and Addington)	www.kflapublichealth.ca	https://www.facebook.com/kflapublichealth/ (2873)	https://twitter.com/KFLAPH (3234)	https://www.youtube.com/user/KFLAPublicHealth (22)
	Porthope (2)	See Porthope			
Champlain	Brockville (2)	See Brockville			
	Cornwall (Eastern Ontario Health Unit)	www.eohu.ca	https://www.facebook.com/EOHUhealth/ (1100)	https://twitter.com/EOHU_tweet (1059)	https://www.youtube.com/user/EasternOntarioHealth (959) https://www.instagram.com/eohucomm/ (124)
	Ottawa*	http://ottawa.ca/en/residents/public-health	https://www.facebook.com/ottawahealth/ (11440)	https://twitter.com/ottawahealth (49.1k)	https://www.youtube.com/user/ottawahealthsante (310) https://www.instagram.com/ottawahealthsante/ (392)
	Pembroke (Renfrew	http://rcdhu.com	No Facebook page	No Twitter page	No social media page

	country and district)	/			
North Simcoe Muskoka	Barrie (Simcoe Muskoka)	http://www.simcoemuskokahealth.org/	https://www.facebook.com/simcoe.muskoka (2891)	https://twitter.com/SMDhealthunit (1486)	
	Owen Sound (3)	See Owen Sound			
North East	Kenora (Northwestern Health Unit)	https://www.nwhu.on.ca/Pages/home.aspx	https://www.facebook.com/TheNWHU?fref=nf (1319)	https://twitter.com/TheNWHU (467)	https://www.youtube.com/user/TheNWHU (17) https://www.instagram.com/thenwhu/ (164) https://www.linkedin.com/company/3508476/ (258)
	New Liskeard (Timiskaming)	http://www.timiskaminghu.com/	https://www.facebook.com/Timiskaming-Health-Unit-108069779257419/ (1297)	https://twitter.com/timiskamingMOH (37)	https://www.youtube.com/channel/UCpwZynPfKEBoT58z4FDu_nA (0)
	North Bay (North Bay Parry Sound)	http://www.myhealthunit.ca/en/index.asp	https://www.facebook.com/NorthBayParrySoundDistrictHealthUnit (1319)	https://twitter.com/NBPSDHealthUnit (1075)	https://www.youtube.com/user/NBPSHealthUnit (18)
	Sault Ste. Marie (Algoma)	http://www.algomapublichealth.com/	https://www.facebook.com/algomahealth (6010)	https://twitter.com/algomahealth (1519)	https://www.youtube.com/user/AlgomaPublicHealth (302)
	Sudbury Timmins (Porcupine)	http://www.porcupinehu.on.ca/en/	https://www.youtube.com/user/PorcupineHealth (585)	https://twitter.com/PorcupineHU (283)	https://www.youtube.com/user/PorcupineHealth (16)
Northwest	Kenora (2)	See Kenora			
	Thunderbay	http://www.tbdhu.com/	https://www.facebook.com/TBDHealthUnit (4413)	https://twitter.com/TBDHealthUnit (2011)	https://www.youtube.com/user/TBDHealthUnit (57) https://www.instagram.com/TBDHealthUnit/ (721)
*Indicate responsible LHINS that will fund public health units according to the new Patients First: Action Plan for Health Care, effective 2018. **Or "public health" or "health services" where indicated					

Chapter 5: Conclusions

The overall objective of this doctoral thesis was to understand the role of social media in addressing vaccine hesitancy through mis-information about childhood vaccines in Ontario. This chapter begins with a summary of the principal findings of each of the three chapters that addressed the overarching research question, aims, and objectives of this thesis. Following this, the substantive, theoretical and methodological, contributions of the thesis as a whole will be considered, followed by a discussion of the strengths and limitations of the study, and its implications for policy and practice, and future research.

Principal findings

Three discrete chapters address the overarching and specific aims of the thesis. Using a mixed methods approach, I demonstrate that analyzing vaccine conversations on a social media platform such as Twitter can be helpful not only in terms of exploring what is being discussed on social media about vaccination, but also for measuring (using network analysis methods) the likelihood that different types of social media users (i.e., with different vaccine sentiment, profession/affiliation, and geographic location) will 'talk' with each other more frequently. Further, by analyzing the *content* of social media using a mixed methods approach, one can explore the association between users' behavioral attributes (i.e., affiliation or profession, emotion, embedded or linked medium, direction of sharing, use of Twitter functions) with the sentiment conveyed towards vaccines. And finally, through in-depth qualitative interviews with decisionmakers and the analysis of key government documents, gaps between current recommendations for social media use and actual practice are identified including the barriers to using social media for addressing the

problem of public confidence in vaccines.

To move towards increasing vaccine confidence, this research has contributed to an understanding of the "on the ground" realities of vaccine hesitancy on social media. This includes a deeper understanding of the perceptions and current practice of decisionmakers towards the use of social media for increasing vaccine confidence. and subsequently, realigning policy recommendations to better reflect the needs of the public and for public health practice. Taken together, the three studies within the dissertation identified the need for an improved alignment between evidence, policy and practice in the area of vaccine hesitancy, uptake and the role of social media.

Chapter 2 aimed to address gaps in our understanding of the public's sentiment towards vaccines using a sentiment and social network analysis of data from Twitter collected between 2013 to 2016 in Ontario during the period of sustained measles outbreaks in Canada. Results show that a small majority of the social media-engaged public and all public health organizations on Twitter are supportive of vaccines. Those with different sentiments toward vaccine were qualitatively observed to attach different values to the same word; distinct words in respective groups were used to reaffirm their support or opposition towards vaccines. The vaccine conversation network has identifiable pro- and anti-vaccine communities, which clustered when news and events related to vaccination were tweeted. The network was observed to have a high reciprocity, with many highly central users connecting with others by sharing news and important events on Twitter.

This study concludes that anti-vaccine sentiment remains prevalent on social media, as evident on Twitter, and that pro- and anti-vaccine users reside in siloed communities that

cluster around news and events, posing challenges to the diffusion of vaccine information across communities on social media. Based on this finding, I suggested that identifying users in unique positions (i.e., influencers, broadcasters, brokers, et cetera) as calculated by their centrality in the vaccine conversation can assist in the strategic design and in enabling how public health professionals approach social media to increase engagement that breaks out of their individual vaccine-sentiment echo-chambers.

Chapter 3 aimed to understand the attributes of those participating in vaccine conversations on Twitter in Ontario. Typologies of user attributes were generated using an iterative mixed methods coding process. Quantitative content analysis was used to measure whether differences in user attributes among different vaccine sentiments, and thematic analysis was carried out to identify common vaccine refusal themes.

The majority of users who express their views on vaccines were members of the general public, followed by accounts held by health-related professionals/organizations/websites, news media companies and news websites and journalistic professionals, and finally by those who established accounts for purely anti-vaccine purposes. Difference in means tests revealed that pro-vaccine users express more positive emotion, retweet and share information to non-specific audiences, and tend to share more text-heavy content than neutral and anti-vaccine accounts. Neutral Twitter accounts tend to share more multimedia links, news links, and were less likely to retweet, mention, or reply, this can be explained by the fact that the majority of neutral accounts were held by news media companies. Accounts with negative vaccine sentiment were more likely to express negative emotions, share more videos and images, and were more likely

to issue calls-to-action using the Twitter mention function. Qualitative thematic analysis show that users with pro-vaccine and anti-vaccine share links with little crossover to links with opposite sentiment. Prominent reasons for negative vaccine sentiment are *alternative evidence, adverse events, mistrust, alternative treatment, and other concerns.* Plausible explanations contributing to observable differences in user attributes of those expressing different vaccine sentiments were explored, followed by a discussion of implications for immunization promotion on social media to increase vaccine confidence, and the benefits of content analysis to the larger public health community to address misinformation on social media.

Chapter 4 aimed to explore the perception of decisionmakers and advisors of vaccine policy and communication on the use of social media in response to the prevailing anti-vaccine phenomenon in Ontario. Using a exploratory case study approach with grounded theory methods, federal and provincial govenrment documents relating to immunization policy and practice were collected, and key informants who are decisionmakers or advisors in policy and communications for immunization were interviewed.

A number of key messages arise from this study. First, the presence of vaccine misinformation on social media is perceived by decision makers and advisors differently depending on their roles contributing to policy or communications related to immunization; second, little explicit consideration has been given to the role of social media in informing the immunization policymaking process; third, the use of social media for public engagement and vaccine awareness is constrained by decision makers' uncertainty about

its return on investment compared to other health promotion approaches; fourth, the implementation of social media as part of a health promotion strategy to engage the public and improve vaccine awareness has not accumulated enough evidence to be confidently implemented by decisionmakers in vaccine policy and communications in Ontario. Contrary to policy recommendations that social media is one of the ways to address vaccine hesitancy, key informants perceived the use of social media as just one other way of promoting vaccine awareness. A multitude of barriers prevent key informants from supporting the use of social media to assess, evaluate, formulate, and implement policies to increase vaccine uptake.

Overall, the three studies taken together, I observe that (1) federal and provincial policy recommendations suggesting the use of social media to address vaccine hesitancy have not been fulfilled at the provincial level due to various barriers and challenges in practice, making the adoption and use of social media at the local level uncoordinated and at the will of individual local PHUs, (2) provincial-level practices and the rules and regulations guiding immunization promotion have not been in sync with the "realities" of the narratives of vaccine hesitancy on social media; the former is concerned of accessibility, factual information, and the importance of clinical interactions; the latter (social media) is concerned on adverse events and are filled with pseudo-experts. In all, the proponents and opponents of vaccines reside in unique echo chambers, each adopting vastly different communication approaches, with little assessment of how to align promotional approaches with the needs of the concerned public who are vaccine hesitant.

Thesis contributions

This thesis aimed to contribute to the broader immunization policy community by addressing substantive, theoretical, and methodological gaps in the understanding of the vaccine-related communities on social media. Further implications of these contributions are discussed in the "implications for policy and practice" section of this chapter.

Substantive

The three original studies make several substantive contributions to the field of health policy. **Chapter 2** and **chapter 3** fill important knowledge gaps by providing a snapshot of '*who is talking to whom, what they are talking about, and how vaccine information is being discussed and passed around*' on Twitter between 2013-2016 when measles outbreaks occurred in Canada. Looking at the conversation from a network perspective, it was identified that a pro-vaccine cluster and an anti-vaccine cluster made up the majority of the network, with uniquely positioned nodes that play vital roles in the dissemination of vaccine information. Chapter 3 adds to the network analysis a layer of sophistication by identifying, coding, and analyzing 6 types of user attributes, which were then tested for significant for their association with vaccine sentiment; content analysis identified 5 themes that supports anti-vaccine claims in Ontario. The study also contributes novel evidence regarding Ontario public health agencies' use of Twitter for promoting vaccination on Twitter. Study findings demonstrate that their communication with others occurs mostly *within* the larger pro-vaccine community and resembles that of pro-vaccine communities in being primarily text-based, non-specific, and limited in addressing the concerns of the vaccine hesitant. While both clusters surrounded news or relevant events,

the siloed presence of the two communities point to a conclusion that online health promotion for vaccine awareness may be ineffective due to its low penetration rate to vaccine opponents both in proximity and by the means through which they converse.

Chapters 2 and **3**, taken together, applied the concept that health-seeking behaviors on social media can be approached from a networked mindset to identify connections, information exchanges, and means of informational exchange. Practically, one can explore issues-based topics such as vaccine hesitancy to measure the prevalence of different vaccine sentiments similar to public opinion polls with appropriate sampling techniques shown in this study. In addition, this study showed that although social media can be seen as a large network, further inspection of its clusters and structure tells the tale of a fragmented community that rests distinctively in echo-chambers with opposite vaccine sentiments connected by uniquely positioned nodes that may serve to influence, broadcast, and act as brokers across communities. Furthermore, as research shows that effects of online behavior spill over to our offline world (Althoff, Jindal, & Leskovec, 2016), the fact that the anti-vaccine community in Ontario was significantly more likely to call for action illustrates the possibility that social media is not a close-looped ecosystem of its own.

Through these studies, I also demonstrated that affiliation or profession, emotion, embedded or linked medium, direction of sharing, use of Twitter functions, and link content are different among those with different vaccine sentiment; and that pseudo-experts may drive dominant discourses used in vaccine refusal on social media. Furthermore, anti-vaccine sentiment prevails on social media but permeates through a conceptually media-hybrid society (Chadwick, 2017). The findings offer crucial evidence for policymakers and

decisionmakers that social media needs to be seen from a networked perspective. By recognizing that nuances in the network structure, connectivity, and user attributes such as the relevance and rise of image and video-based content among the anti-vaccine and their need to call-for-action are all determinants of information dissemination, it is possible to formulate immunization policies that promote vaccine confidence.

Given that no previous research has explored the use of social media to increase vaccine confidence in the context of Ontario despite government recommendations to do so, **chapter 4** provides substantive contributions to understanding policymakers' perceptions of vaccine hesitancy in an era of online vaccine misinformation, and the considerable challenges to be faced in increasing vaccine confidence through social media in Ontario. Despite provincial recommendations seeking to increase vaccine confidence through social media, varied perceptions towards vaccine hesitancy, concerns about return on investment, lack of logistical and programmatic support, and most importantly, lack of evidence on the effects of social media for health promotion made policymakers hesitant to explore the use of social media to address behavioral change. Conceptually, these findings suggest that depending on the level of practice (provincial versus regional) and position (communications versus policy adviser), the lack of consensus towards the use of social media precludes considerations and actions towards addressing vaccine hesitancy. Beginning with an understanding of the affordances of social media and conversations about vaccines that occur on the siloed clusters on social media can help policymakers identify the types of vaccine hesitancy concerns relevant to Ontario, the kinds of user attributes present in anti-vaccine sentiment clusters, and ultimately make use of the data

and affordances of social media platforms to analyze and design strategic promotion and protection programs for the public good.

As a collective set of chapters, this study contributes to a deeper understanding of an example of i) an extreme public health topic in terms of public opinion akin to water fluoridation, milk pasteurizing and vaping; ii) a typical public health information dissemination platform by both public health agencies and the anti-vaccine, in contrast to other more aggressive anti-vaccine platforms such as Facebook, YouTube, and Pinterest that public health agencies are less involved in; and iii) a typical yet emerging challenge among most jurisdictions globally such that the public health infrastructures and guidelines are not fully established to respond to VPD outbreaks without the inclusion of social media or consideration of public opinion on social media. In this case study, immunization policymaking in Ontario has several characteristics: (1) despite policy recommendations to increase vaccine uptake through the use of social media, social media is currently being used primarily for information dissemination purposes; (2) policymakers claim that the effectiveness of immunization interventions on social media are inconclusive and "low-hanging fruit" yield greater results, but little consideration was given to the limitations of conventional public health interventions, which are largely unable to overcome the "echo chamber" effect on social media, and (3) to increase the feasibility of designing social media strategies that are reflective of observations of vaccine hesitancy on social media, one needs to "be where the conversation is".

Theoretical

Chapter 2 and **chapter 3** contributed towards a more robust conceptualization of

social media discourse by drawing theoretical insights from different disciplines (e.g., network theory, theory of communicative action, the affordances of social media platforms) to develop a fuller interdisciplinary understanding of the use of social media by the public, public health agencies, and the vaccine hesitant. The theoretical foundations that inform vaccine hesitancy research must expand beyond traditional health communications theory (e.g., theory of planned behavior, health belief models, et cetera) and explore both theoretical and empirical advancements from other academic disciplines to account for the variability of user attributes between different vaccine sentiments that social media platforms provide.

Chapter 4 used a case study approach to reveal that policymakers are just beginning to understand social media. Frameworks such as the 4 pillars of social media adoption for e-governance in public health (Tursunbayeva, Franco, & Pagliari, 2017) and the stages heuristic model of policy development were alternative propositions used to help explain the perception and responses to vaccine misinformation on social media by policymakers. The findings from this study revealed that these propositions fell short as theoretical frameworks that would explain policymakers' views on this topic. Theoretically, this study complements other examples of non-adoption of social media or partial adoption of social media strategies in policymaking environments in which a "need-to-know paradigm" (Dawes, Creswell, & Pardo, 2009) underlie the policies and mandates of government communication in which the support for social media adoption are determined by the past experiences of technology use that once set, "unrealistic, misaligned expectations, process, incentives, and assumptions are hard to change" (Dawes et al., 2009, p.399)" . In essence,

despite literature on government use of social media to engage the public in early phases of the policymaking process, co-create policies, and evaluate programmatic outcomes (Tursunbayeva et al., 2017), the inherent dismissal towards social media in consideration of the underlying the logistical, legal, and resource constraints that impede government uptake of new technologies in Ontario highlights the need to mitigate discrepancies in the perceptions towards social media and its use may be to draw lessons from public health institutions elsewhere and establish clearer goals for social media use for the specific context of in Ontario.

Methodological

This thesis makes several methodological contributions through the mixed-methods approach used to analyze networks and policy making on a polarizing public health topic – the case of vaccine misinformation on social media. First, the network and sentiment analyses carried out provided a novel and robust avenue for exploring or validating other sources of public opinion on this topic. A purely quantitative sentiment analysis would have only measured the prevalence of vaccine hesitancy. In contrast, the use of a mixed-method content analysis approach in this study provided additional depth to the analysis, for example, through the review of external links, the sentiment attached to these links, and the sentiment of those who tweeted them, to make sense of what people in Ontario thought about vaccination. Overall, the value of social media data collection was demonstrated through the hundreds of publicly available Twitter data points, creating an accessible and invaluable opportunity to "listen in" without the need to survey in-person, conserving resources and time.

Second, case study methods were applied in rigorous and novel ways to explore and understand the immunization policymaking landscape in Ontario. The use of triangulation in both the sampling and data collection stages as well as in the analysis of data embedded highly rigorous methods throughout the study. Drawing on a myriad of sources (e.g., news, social media, published papers) to identify key informants in Ontario, triangulation was achieved by comparing government documents, public records to communications materials provided by key informants and the verbatim of key informant interviews. The blending of traditional case study methods with the use of grounded theory for the key informant interviews allowed policymakers to make sense of the use of social media in ways that were meaningful to them and that allowed for novel themes to emerge that a more structured approach to data collection would not have permitted. While presenting more challenges for analysis, the findings generated using this approach may provide richer insights that can be acted upon and, ultimately, used by public health professionals, healthcare professionals, policymakers, academics, and communications strategists, and the public.

Implications for policy and practice

The findings from this thesis have several implications for policy and practice. First, the study revealed the multi-level discrepancies between policy recommendations and practice by policy and communications decisionmakers (shown in chapter 4) and the needs and concerns of the public (shown in chapter 2 and 3). These findings will hopefully provide useful contextualization for policymakers and practitioners in the public health field to realign recommendations, policies, and practice to strengthen the public's

confidence in vaccination.

Three policy implications are to be considered based on our study. First, the study found that federal and provincial recommendations, while laudable, do not reflect the reality of immunization policy and practice at the local level. Competing priorities, a multitude of logistical and financial constraints, lack of guidance and lack of coordination between multiple levels all inhibit the uptake of recommendations. Second, how practitioners in public health use social media to promote vaccine awareness. In chapter 4, the themes that did not emerge are just as important as what did emerge. Although public health agencies and health-related organizations participate in health promotion on social media, it was not apparent that interviewees necessarily understood the vaccine-hesitant audience, what their concerns were, or what general themes of misinformation they were exposed to or sharing, etc. This deficiency is reflected in the health promotional methods used (i.e., factual information), materials developed (i.e., text-based), and communities the information is being promoted to (i.e., non-specific, general audience residing in predominantly pro-vaccine clusters). This leads to the third policy implication of this study, which is that current techniques for using evidence to inform immunization policies, including scientific evidence and evidence generated from public participation in the design of social media strategies are outdated. Recalling that the federal government provides funding for government organizations to assess the knowledge, attitudes, and practices of the public to increase vaccine uptake, the funded organizations mainly focus on information dissemination without considering the impact of networks, let alone the nuances of user attributes on social media. Although the Canadian Immunization Research Network

(CIRN) includes influential researchers exploring vaccine hesitancy, it is apparent that current evidence cited to increase vaccine confidence remains heavily focused on one-way information dissemination using education. While interviewees' concerns about "backfire effect[s]" and "insufficient evidence" to support the use social media to promote vaccine awareness are valid, this reflects the current climate that no solid evidence means no action, and thus addressing vaccine hesitancy is largely reactionary.

The first implication for practice pertains to the need for collaboration with broker to bridge opinions, such as leveraging the structural position of the Minister of Health in the Twitter conversation to initiate pro-vaccine campaigns that bridges structural divides across the vaccine network. Second, because user/demographic characteristics of social media platforms (e.g., internet-users) differ from traditional provincial population surveys (e.g., those who pick up the phone or have land-lines), network analysis through collaboration with academic institutions with established social media laboratories with the capacity to monitor the spread of misinformation may serve as a less labour-intensive method (as compared to conducting network analysis in-house by public health agencies) to complement population surveys to observe vaccine misinformation as they occur. Third, informed by chapter 3, an understanding of the modes of communication and behavioral attributes can serve as a precursor to creating better strategies to reach desired constituents, ensuring that accurate, coherent, and trustworthy vaccine information are easily accessible to the public. As well, considerations must be given to moderating pseudo-experts such as regulated or unregulated complementary and alternative medicine (CAM) practitioners (e.g., naturopaths, homeopaths, etc) and chiropractors within and outside of Canada who

disseminate misinformation that are outdated, untruthful, incomplete, or fabricated to promote anti-vaccine agenda.

In the context of Ontario, one has to ponder the effects of policymakers' current disregard for social media and whether it would set the tone for future directives in the consideration of social media use to address health misinformation. When making evidence-informed decisions for public health communications, a shift in emphasis is needed from asking '*how can we provide immunization information?*' to '*how can we create a network of influencers that addresses the concerns of the public?*'. Public health promotion strategies might wish to avoid siding with or allowing campaigns to foster public discourse that denigrates vaccine refusal parents. Increasingly, akin to processes of radicalization and violence on social media (Archetti, 2015), vaccine hesitant groups have gone into "hiding" to avoid attacks from opposing commentaries (e.g., deleting pro-vaccine comments in anti-vaccine private groups). Campaigns and regulations that have elements of judgement and factual evidence provision work against the favor of immunization promotion (Tucker et al., 2018; Silverman & Wiley, 2017). Drawing lessons from this study, government organizations and public health agencies are encouraged to collaborate with a wide-range of researchers in academic institutions (e.g., communications and information, geoinformatics, et cetera) to understand vaccine hesitancy on social media. The considerations derived from this study as well as collaborative successes from marketing and communications case studies in public health should not be overlooked as less important than health-sciences evidence. The above considerations may potentially provide insights into the design of successful campaigns and communication strategies that

value "listening in", moreover, to pay attention to nuances between those with opposing opinions in vaccines, and to avoid factual provision of information devoid of emotional connection to the vaccine-hesitant public.

Strengths and limitations

This thesis has several strengths. First, social media use for policymaking has been underexplored in the context of Canadian policymaking; this study addressed knowledge gaps about *how* vaccine hesitancy is perceived by key contributors to immunization policymaking, *why* social media is only used for information dissemination, and *what types* of approaches are being prioritized to increase public confidence in vaccines. Second, using Twitter data to collect publicly available APIs and analyzing network properties provided a novel way of understanding of the prevalence of vaccine hesitancy on Twitter in Ontario. The special attention given to the ethical considerations surrounding data collection on social media ensured that all tweets were anonymized, with the exception of those from public figures.

The novel approach of mixed methods content analysis used in chapter 3 categorized, quantified, and analyzed the types of medium and links being shared by different vaccine sentiments that accentuated that imagery and video-based information perpetuate anti-vaccine messages.

Finally, this thesis applied an interdisciplinary approach drawing on literature from information and network science, communications theory, public health, policy sciences and public administration to inform the conception of the study, its methodological features and analytical insights. By adopting this approach, this provided the opportunity to apply

the most relevant disciplinary tools to tackle this complex topic and to allow for the dissemination of its contributions through relevant scientific, policy and practice networks.

The thesis also has several limitations. First, our study did not measure the association of socioeconomic variables such as gender, income, educational attainment, ethnicity with vaccine sentiment. This is due to the ease of remaining anonymous when searching or spreading health-information online, and the fact that half of the Twitter accounts were organizational accounts that are without demographic identifiers. This limitation, shared by researchers collecting data on social media, poses challenges to the design of public health promotion and protection where the target audience and communities are easily identified. Second, the rather small sample size collected in our study over the 3-year period is a result of strict inclusion criteria. The dataset used Twitter's standard search API (providing 1% of all tweets in its API), restricted the search to exact keywords (instead of keywords and its derivatives) in the query, and only included tweets from Ontario, marking Toronto as the centre and capturing tweets within a radius of ~150 miles from the metropolitan. Third, concerning the study design of chapter 4, the term "social media use" in the semi-structured interview may have impeded the interviewees' attempt at understanding the heart of the question concerning social media use. Which is not only how it is being used to address vaccine hesitancy, but how can it be used. It is possible that interviewees concern "social media" and "use" with the responsibility of communications strategists. Despite guiding interviewees to think about how social media can be incorporated in informing policymaking processes, the interviewees were more concerned about the more 'practical' affairs that can increase public confidence.

Implications for future research

While this thesis makes important contributions to the immunization policy community, it also raises additional questions that are worthy of exploration in future research studies. First, the permeation of pseudo-experts warrants attention given the volume and reach on social media, and their attempt to portray physicians who persuade parents to vaccinate children as "misinformed" (Raines, 2017). This also raises questions that challenge the traditional public health notion of approaching influence as one with identifiable source and end-audience, and further, raises important concerns that the accessibility, readability, and approachability of evidence conducted in scholarly institutions are not penetrable in an environment filled with "relatable" pseudo-experts promoting vaccine misinformation to demographics believing in "natural and organic" lifestyles in Ontario.

To address these questions and challenges, future studies in this area might focus on evaluating the influence of CAM practitioners on social media– anti-vaccine ideologies towards vaccines are prominent among chiropractors, naturopaths, and other CAM practitioners, all of whom are legal to practice in Canada as licensed professionals (Chambers, Buxton, & Koehoorn, 2010; Ernst & Smith, 2018; Lawrence, 2012). Emerging research points to opportunities to predict behavioral changes after multiple exposures to repeated misinformation on social media (Zhu, 2017), leading to a shift of social conventions/behaviors when a tipping point of 25% is reached (Centola et al., 2018). Studies applying network theory may help explicate homophily from contagion using simulated network interventions such as Temporal ERGMs or SIENA (Simulation

Investigation for Empirical Network Analysis).

Second, vaccine hesitancy studies on social media would benefit from borrow lessons from studies on the polarization and proliferation of extremism, social ideologies, political discourse on social media platforms. The affordances of Internet have created debates amongst scholars who conducted meta-analyses on the effectiveness of public health interventions, political campaigns, and democratic participation on the population's behavior and beliefs (Boulianne, 2015; Skoric, Zhu, Goh, & Pang, 2015), such that these "comprehensive aggregate studies offer evidence that the effects of social media consumption and use are hardly uniform across different contexts and groups (Dimitrova & Matthes, 2018)".

Third, future research would benefit from prioritizing the barriers that need to be address to create best practices for social media informed by a commitment to timely knowledge translation. Possible means include evaluating and learning from countries that are transparent about their immunization policies (e.g., disclosing data and establishing compensations for adverse effects following immunization (AEFI) by trusted provincial health agencies), as mounting evidence suggests that trusted institutions and health experts that directly address the public concerns on the risks of vaccination may alleviate the anxieties towards vaccines (Vraga & Bode, 2017).

A final area for attention is the need to establish frameworks and best practices for social media use for the public sector, informed by a deeper knowledge of the ethical conduct, business models, and incentives of international technology companies (e.g., Twitter, Facebook, Google). Currently, the public sector's concerns about using third-party

technological company services discourage broader use of social media. Companies like Twitter have implemented moderating features to prevent online misbehaviour such as removing accounts and hashtags promoting violence and radicalization, although such efforts are not without pushback from other technology companies that are sustained by niche interest groups, and those who perceive content moderation as paternalistic and subjective to the agendas of those who govern (Gerrard, 2018). Sophisticated, evidence-informed frameworks will be needed to guide the public health community through this complex terrain.

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