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Social Media Communication about HPV Vaccine in China: A Study Using Topic Modeling and Survey

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ABSTRACT

The human papillomavirus (HPV) vaccine is relatively novel to people in China. Social media is becoming an important channel for learning new health information. However, limited is known about what HPV vaccine information has been disseminated on social media, and how such online information is associated with health-related behaviors in China. Based on Longo et al.'s model of patient use of healthcare information for healthcare decision, and Longo's model of health information seeking behaviors, this study examined HPV vaccine-related information type and information acquisition pattern. Following the mixed-methods approach, we first crawled 67,773 postings about HPV vaccine on Weibo, the largest microblogging website in China, and performed topic modeling to identify HPV vaccine-related topics that are prevalent on Weibo. The results showed six major topics about HPV vaccine, namely policy, guidance information, advertising, scandals, personal experience sharing, and HPV risks. Second, we conducted an online survey (n = 1,982) to investigate how scanning, seeking, and discussing the six HPV vaccine topics identified from big data analytics can affect HPV vaccine knowledge, safety concern, and vaccination intention. We documented significant impacts of social media health communication on users' health knowledge, attitude and behavioral intention.

Introduction

The human papillomavirus (HPV) vaccine is relatively new to people in China, as the first 9-valent HPV vaccine was approved in 2018. The public awareness about HPV vaccine still remains low (Li et al., 2018). During the recent decade, social media has become an important platform for learning new health topics (Shi et al., 2018). On social media, users can get exposure to real-time health news created by media agencies, and medical information disseminated by health care organizations. Social media also allows users to create, share, and discuss health information with others online, promoting collaborative learning to gain new health knowledge, such as HPV vaccine (Ansari & Khan, 2020). Health benefits of social media have been widely documented, such as greater social support, more available and shared information, and public health surveillance (Moorhead et al., 2013).

Despite the importance of social media use for health information, there is an inconsistency in its effect on health knowledge and beliefs. Some past studies demonstrated the positive effect of social media use. For example, Ortiz et al. (2018) found receiving HPV and HPV vaccine-related information on social media improved young people's knowledge about the virus and vaccine. However, other studies documented an insignificant relationship between social media for health information and health beliefs. For instance, seeking COVID-19 information on social networking sites had insignificant impacts on subjective norms and risk perceptions (Liu et al.,

2020). Even more concerning, Allington et al. (2021) found that social media use for COVID-19 vaccine information decreased vaccination intentions. These mixed findings are captured in a systematic review by Strømme et al. (2014) which concluded that it is unclear whether health-related social media use increased or decreased health knowledge, attitude and beliefs. To explain such discrepancies in the effect of social media use on health learning and prevention, it is essential to have a fine-grained understanding of individuals' health information use. Longo et al.'s (2001) model of patient use of healthcare information for healthcare decision, and Longo's (2005) model of health information seeking behaviors offer the sound theoretical underpinnings to explore users' information behaviors. The first model highlights that one's use of different types of health information can lead to different health-related outcomes. Without specifying what topics of media messages are associated with which particular outcomes, important media effects would be obscured. The latter model focuses on information acquisition patterns, stating that different ways in which individuals obtain information (e.g., passive receipt vs active seeking) may result in different health outcomes. Although these two theoretical models demonstrate two key aspects of information behavior, namely information type and information use pattern, few studies have investigated how social media use derives effects on health-related outcomes, according to both messaging content type and information use type simultaneously. Also, most past studies examined

two information use types, information scanning and information seeking, while information discussing has been relatively under-researched. Given the interactive nature of social media, it is crucial to examine how the two-way information discussion and exchange will influence health.

Therefore, to have a more nuanced understanding of how social media use for health information influenced health-related outcomes, we selected HPV vaccine as the health context, explored topics about HPV vaccine on Weibo, the largest microblogging website in China, and investigated how scanning, seeking and discussing different HPV vaccine-related topics were associated with different outcomes, including users' HPV vaccine knowledge, attitude, and behavioral intention. The findings from our study will not only extend health information models (Longo, 2005; Longo et al., 2001) by taking into account both information type and information use on social media, but also enable health communication practitioners to formulate more targeted and effective communication strategies in the digital era. In the next section, we first review the theoretical foundation of this study, and then explain the basis of our theoretical extension.

Theoretical foundation

Our study is based on Longo et al.'s (2001) model of patient use of healthcare information for healthcare decision, and Longo's (2005) model of health information seeking behaviors. Today's digital age provides individuals with diverse health information for decision-making. Longo et al.'s (2001) model suggests that different information types result in different health-related outcomes (e.g., beliefs, motivation, locus of control). Therefore, the core tenet of this model is to understand the *type* of information, which refers to the specific topic of information. Longo et al. (2001) proposed several examples of information types, such as information on the disease and disease process, information on self-care and self-management strategies, and information on specific health services and treatments.

Longo (2005) later acknowledged that one limitation of Longo et al. (2001)'s model is that it fails to consider how different information *acquisition patterns* (i.e., active seeking, passive scanning) affect health-related outcomes. In the model of health information seeking behaviors, Longo (2005) stated that health information is not always sought purposively. In many situations, people are likely to come across information accidentally during their routine pattern of media consumption. Thus, Longo (2005) suggested to better understand both active information seeking and passive receipt of information.

In the present study, we aim to advance these health information models (Longo, 2005; Longo et al., 2001) from two aspects. First, we propose an integrated model by considering both information type and information acquisition pattern simultaneously. Individuals consume various types of health information to satisfy their information needs. However, the impact of different information types would vary vastly. For example, information about HPV and cervical cancer might be important to enhance understanding of the virus and its negative consequence, but it might not affect people's perception of safety of HPV vaccine, due to irrelevance. By emphasizing

information type, the model offers a nuanced examination of media effect from the message topical perspective. Despite the need to consider specific information type, it is equally important to investigate information acquisition pattern. We argue that the same information type, if obtained and consumed in different manners, might result in dissimilar effects. For instance, *information scanning* features the passive information acquisition where information is encountered without being sought. With information scanning, people obtain relevant and useful information incidentally during their routine patterns of information exposure. *Information seeking*, on the other hand, is a purposeful acquisition of information from selected information sources, and requires active efforts to obtain specific information outside the normal pattern of information exposure. Second, we distinguish between one-way and two-way information acquisition patterns. Passive information scanning and active information seeking are deemed as the one-way information acquisition, as it does not emphasize information exchange. In our study, we break new ground in adding *information discussing*, a two-way information acquisition behavior. Information discussing centers on exchanging opinions, sharing insights, giving feedback, asking questions or collaborating on problem-solving (Jiang & Liu, 2020). This enriches users' health-related knowledge, and enables them to develop a sense of social cohesion and belonging, increasing their confidence in overcoming health threats. The two-way information acquisition is particularly salient on social media, an interactive digital platform where people can engage in communication with others about health-related issues.

In sum, inspired by Longo et al.'s (2001) model that highlights the importance of information types in healthcare experiences, our Study 1 aims to examine the different topics of HPV vaccine information on social media. In addition, based on and expanding Longo's (2005) model of health information seeking behaviors, our Study 2 aims to explore how scanning, seeking, and discussing different information types can be associated with people's health-related outcomes.

Literature review

Social media health communication

The recent decade has witnessed an increasing usage of social media for health information. Social media can contribute significantly to health education and promotion, due to its high uptake rate and ability to spread information quickly, allowing the general public, health care organizations and government agencies to engage, interact and communicate with each other about health issues (Thackeray et al., 2012). On social media, health care organizations and providers can leverage on this platform to provide accountable and educated advice, ensuring that the public will be able to find accurate and reliable health information (Welch et al., 2016). Social media also enables peer-to-peer health support, where the public is able to engage with others who share similar medical conditions, or as caregivers to those who suffer from medical conditions (Zhu et al., 2020). The two-way communication pattern of social media allows people to find validation and encouragement to pursue and maintain healthy habits (Chung, 2014).

Social media offers connectivity and has potentials to be the spark of connective action (vis-a-vis collective action) leading to community-led shifts in health behavior (Vicari & Cappai, 2016).

Ample evidences for the effectiveness of social media health communication for public health have been reported. For example, individuals who used social media for smoking cessation showed positive changes in determination to quit as well as their actual quitting behaviors (Naughton et al., 2012). Social media health information increases patient engagement, and provides greater opportunities for individuals to find social support, leading to health behavioral changes (Jiang & Ngien, 2020). Patient participation in online discussions was associated with better socio-psychological well-being, empowerment and self-efficacy in health management. HPV vaccine information is not uncommon on social media in many developed countries. For example, in the United States, (Dunn et al., 2017) analyzed Twitter data and found that HPV vaccine information has been increasingly disseminated on social media since 2006 when the first HPV vaccine was available. Similarly, in European countries, such as Denmark, Facebook was widely used for health campaigns to promote HPV vaccination (Loft et al., 2020). Given that HPV vaccine is still novel in China, it is critical to understand what information and topics about HPV vaccine are circulated on social media. Thus, we proposed the first research question:

RQ1: What HPV vaccine-related information is disseminated on social media in China?

Health information acquisition behaviors: seeking, scanning, and discussing

Health information seeking refers to the purposive seeking behavior for health information to reduce health-related uncertainty or satisfy other goals (Anker et al., 2011). Health information seeking on social media thus emphasizes one's initiative to actively search for needed information outside the normal flow of social media use. For example, social media offers the search engine function, which allows users to look for health topics of interest (Xiang & Gretzel, 2010). People can also turn to a specific organization's social media public page to locate information they desire. In the context of China, people have reported more frequent health information seeking on social media in the past several years (L. Zhang et al., 2020).

Health information scanning is defined as one's information acquisition manner that occurs within routine patterns of exposure to mediated and interpersonal sources that can be recalled with a minimal prompt (Niederdeppe et al., 2007). In contrast to active health information seeking, the idea of scanning emphasizes the passive learning process of incidental exposure to the information (Shim et al., 2006). Scholars suggested that with information scanning, people might encounter health information in their daily regular social media usage, or when browsing news from social media (Kelly et al., 2010).

Health information discussing stresses the two-way information exchange, which differs from one-way information seeking or scanning (Longo, 2005). On social media, an interactive platform, individuals can communicate and discuss health information with others. Instead of a single person's interpreting and absorbing information alone, the two-way information discussing allows people to ask questions, receive feedback, exchange opinion, and collaborate with each other to improve self-management (Jiang & Liu, 2020). On social media, family members and friends are important sources to discuss personal health issues. Also, online health communities play a key role in facilitating health information discussing among peers who face the similar health problem (Nambisan, 2011).

Different types of information acquisition function differently in influencing health-related learning and behaviors. Specifically, *information scanning* demonstrates passive learning that happens when information exposure affects what users come to know without paying direct attention. Individuals come across a topic that may trigger a preexisting interest or pique a new interest, which prompts attention and retention of that information, which is encoded in memory and able to be retrieved at a later time (Niederdeppe et al., 2007). In contract, *information seeking* focuses on goal-directed and active searching behaviors. The information acquired by seeking is incorporated into one's existing knowledge. Lewis (2017) summarized that information seeking is characterized by the centrality of individuals' particular needs for information, the deliberate nature of the information activity, and the process of filling in gaps in the knowledge base. *Information discussing*, however, goes beyond searching for or paying attention to information, highlighting the role of learning from peer interactions, such as exchanging information, sharing experiences, and providing encouragement and motivation. By discussing health issues with other people online, users can obtain more support and guidance to cope with health challenges (Ngien & Jiang, 2021).

The influence of health information acquisition on health knowledge, attitude, and behavioral intention

Health information acquisition has the potential of changing people's knowledge, attitude, and practice on health issues. Scholars posit that health information acquisition is the process of discovering messages that address health concerns (Liu et al., 2016). First, health information can reduce uncertainties about health-related situations. The uncertainty reduction theory suggests that when individuals encounter uncertainties that elicit negative emotions, they would be prompted to reduce and manage uncertainties through acquiring additional health information that helps increase knowledge and understanding (Berger & Calabrese, 1975). This also improves their locus of control and promotes motivations to overcome health challenges. Second, when people share and discuss health information with others (e.g., family and friends), they engage in collective sense-making of complicated health threats (Barak et al., 2008). Such information

acquisition provides them a clearer picture of the health issue at hand, increases self-efficacy in health management, and facilitates the sense of empowerment (Atanasova & Petric, 2019). This advantage is particularly salient on social media, an interactive platform, where users share personal experiences and offer instructions that lay people can easily understand and follow, leading to knowledge gain and health belief change (Lee et al., 2012).

Prior research showed that information scanning was influential in changing health-related outcomes (Chatterjee et al., 2009). Health campaigns via mass media were generally carefully planned, well executed, and attained adequate audience exposure (Elder et al., 2004). There has been strong evidence that public exposure to health campaigns was effective in health behavior change. For instance, a systematic review of physical activity mass media campaigns and their evaluation from 2003 to 2010 demonstrated that beyond awareness raising, such campaigns have been successful in increasing actual physical activities across different segments of population (Leavy et al., 2011). In the context of HPV vaccination, Li and Li (2020) found that media attention positively affected people's attitudes toward HPV vaccine and its uptake intention.

Different from information scanning, information seeking is goal-oriented, featuring that people are active in locating information to satisfy their specific needs. Studies illustrated that health information seeking plays a pivotal role in health management (Niederdeppe et al., 2007). For instance, Shim et al. (2006) compared cancer information scanning and information seeking, and found that active information seeking would be more likely to help people obtain adequate information, and lead to subsequent behavioral change. Also, Lin et al. (2016) also contended that health information seeking in the Web 2.0 age was associated with better understanding of health issues, reduced health uncertainty, and more open self-disclosure a personal health online.

Researchers also highlighted the significance of proactively discussing health information via the Internet, which centers on two-way information exchange that increases bidirectional flow of information (Ramanadhan et al., 2013). Empirical evidences supported the importance of discussing health information. For example, Basu and Dutta (2008) found that health information discussing with others in online communities could improve patients' medical knowledge and health literacy. Likewise, Ford and Kaphingst (2009) indicated that individuals who frequently discussed health information with family and friends would be more than twice as likely to have an optimistic view toward cancer prevention.

With a basis of the literature on the relationship between health information acquisition and health-related knowledge, attitude, and behavioral intention, we put forth the following research questions in the context of HPV vaccine:

RQ2: How is HPV vaccine *information scanning* on social media associated with users' HPV vaccine knowledge and attitude, and vaccination intention?

RQ3: How is HPV vaccine *information seeking* on social media associated with users' HPV vaccine knowledge and attitude, and vaccination intention?

RQ4: How is HPV vaccine *information discussing* on social media associated with users' HPV vaccine knowledge and attitude, and vaccination intention?

Two studies were conducted to answer the research questions above. Study 1 aimed to demonstrate what HPV vaccine-related topics are prevalent on social media in China (RQ1), using topic modeling. The purpose of Study 2 was to investigate how scanning, seeking, and discussing HPV vaccine-related topics identified from Study 1 can be associated with knowledge, attitude, and intention of taking HPV vaccine (RQs 2–4), using an online survey.

Study 1

Methods

We collected posts from July 1, 2018 to June 30, 2019 on Weibo in China. This timeline was chosen because the nine-valent HPV vaccine was approved in China in June 2018 (Chen, 2018). This news has significantly amplified public attention to HPV vaccine in China. Therefore, it is important to investigate what information about HPV vaccine has been disseminated on social media after the vaccine becomes available in the market. Three terms, "HPV vaccine," "HPV vaccine injection," and "HPV infection," were adopted to search for all HPV vaccine related content. Data were obtained via Yuqingtong, a data service provider which is a subsidiary of Weibo and thus is authorized to search and use data in its database.

Before conducting topic modeling, the text collection must be sanitized of undesirable components, because the input vocabulary strongly affects the reliability, interpretability, and validity of the topic model (Maier et al., 2018). Thus, we pre-processed the text by removing irrelevant posts[1] from the full dataset. These procedures resulted in a massive reduction of content, with the final data volume of 67,773 posts.

Then, we followed pre-processing steps for Chinese texts, including removing punctuations, eliminating stop words, and segmentation. The segmentation was conducted in *Python* using *Jieba*, a package to separate sentences into words and phrases in Chinese. Considering the differences between HPV and general topics, we adopted a medical-related dictionary and added several specific terminologies that are particularly pertinent to this analysis. We also combined words and phrases with duplicated meanings to optimize segmentation result.

Prior to the topic modeling analysis, we extracted word types with substantive meaning, such as nouns, verbs, adjectives, adverbs, etc., because such words have been found to be useful and efficient in identifying topics in social media texts. Furthermore, considering the characteristics of language distribution, we used relative pruning to remove 5% of the extremely rare words from the corpus, which could considerably enhance the performance of the algorithm and stabilize the stochastic inference of the LDA (Maier et al., 2018).

We used unsupervised machine learning in the form of Latent Dirichlet Allocation (LDA) Topic Modeling to group bags of words in posts (N = 67,773) into different topics. It is

a probabilistic model that learns the latent structure (or topics) of a corpus of text documents (Blei et al., 2003). The LDA analysis was conducted with *Python* Package *gensim*.

As our LDA is unsupervised, three important parameters, namely the number of topic, K, the hyperparameter for the prior on the topic distribution of the document and the prior on the term distribution of the topic, α and β, must be defined in advance. The selection of three model parameters (K,α,β) in this study followed a two-step approach: In the first step, we systematically varied different combinations of K (from 2 to 30) and α (0.01, 0.03, 0.1, 0.3, 0.5, 0.7, 1). The value of β was fixed as 1/K, as suggested in a previous study (Wallach et al., 2009). Thus, all possible combinations of K and α were computed (i.e. 210 models), and each model was run with 1000 iterations. With regard to the index of perplexity and the internal coherence of the model, the result indicated a solution between K = 7 and K = 15. In the second step, we conducted a qualitative investigation of these candidate models to judge the understandability and coherence of the top 50 terms for each topic and the documents assigned to each of them (Roberts et al., 2016). The Rank-1 metric was also used to identify topics of less importance (Evans, 2014). All authors of this study engaged in discussions about which candidate model most suitably represented the content of HPV vaccine-related information on Chinese social media. Finally, we found a model with the parameters K = 10, α = 0.5, and β = 1/K = 0.1 to be the most stable and interpretable.

The last step of topic modeling analysis was to dismiss irrelevant topics and to group, label, and describe the topics. After reviewing the words with the highest probabilities for each topic and reading through a sample of documents featuring high proportions of the respective topic, we dismissed the inconsistent topics from the chosen model, and labeled and described the final model (Maier et al., 2018). The top 50 terms for each topic were sorted by relevance from high to low, and 50 documents with a high probability for each topic were provided to check for intra- and inter-top validity (Quinn et al., 2010). Finally, we found that utilizing six topic categories was optimal. When summarizing the six topics, we also took into account relevant topic categories found from prior research conducted in other countries, such as the United States (Love et al., 2013), and Australia (Surian et al., 2016). Based on both our statistical indictors of optimal topic models as well as past literature, we then decided on labeling the topics depicting the diversity of social media content in HPV vaccine-related posts in China.

The topic modeling results were also compared with human evaluations. Three coders who had never seen the data were asked to read a total of 120 documents, with a high probability for each topic, and decide individually which topic the document corresponded with. The result

Table 1. Topics in identified corpus.

Topic	Rank-1 (% of corpus)	Top terms
Guidance information	24.17%	"cervical cancer," "infection," "vaccination," "prevention," "sexual behavior," "virus," "cancer," "suggestion," "protect," "treatment," "knowledge"
Personal experience	22.09%	"sad," "getting vaccination," "arm," "feelings," "happy," "disappoint," "sisters," "hope," "hesitate," "add oil[2]"
Policy	7.34%	"book," "arrangement," "vaccine," "queuing up," "phone number," "community," "snapping up," "quota," "difficult to book," "announcement," "starting vaccination"
Scandals	5.63%	"hospital," "selling fake product," "tip-off," "Hainan," "incidents," "policeman," "penalty," "manufacturing fake product," "involving counterfeit product," "smuggling"
Risk of HPV	3.71%	"cervix," "woman," "cervical erosion," "infection," "inflammation," "cervicitis," "cervical cancer"
Advertisement	37.06%	"Hong Kong," "book," "Korea," "Cheju," "Renhe[3]," "share," "HK dollar," "markup," "group purchasing," "recommendation"

indicated that 108 out of 120 documents were in agreement with the classification of topic modeling analysis, thus the six topics were kept for further analysis.

Results

RQ1 explored what types of HPV vaccine-related information are disseminated on social media. Using LDA modeling, as shown in Table 1, we found that HPV vaccine was mainly discussed around six topics, namely (1) guidance information, (2) personal experience, (3) scandal of HPV vaccine, (4) policy information, (5) HPV risks, and (6) advertisement of HPV vaccine. Specifically, HPV vaccine advertisement was the most common topic (37.1%), and guidance information that introduces HPV vaccine was the second most common topic (24.2%), followed by personal experience of getting HPV vaccination (22.1%), HPV vaccine policy information (7.3%), and scandal of HPV vaccine (5.6%). The least common topic was HPV risks (3.7%).

The topic of *guidance information* was generally the introduction of HPV and HPV vaccine, and instructions regarding which HPV vaccination gained the most attention. The topic of *personal experience* encompassed a wide range of descriptions of individual users' vaccination experiences as well as expressions of feelings related to their experiences. The topic of *HPV vaccine scandal* included discussions of several instances of malpractice in some clinics involving the use of counterfeit vaccines in mainland China (mainly in Hainan province) and Hong Kong SAR. The topic of *policy information* contained information and discussion about supply shortages of HPV vaccine shots in China and the policy of the booking system for HPV vaccine in China. The topic of *HPV risks* addressed issues related to the risks of HPV infection and

Table 2. Socio-demographic characteristics.

	Number (%)
Age	36.9(10.46)
Gender	
Male	891(45.0%)
Female	1091(55.0%)
Education	
Below high school	33(1.7%)
High school	242(12.2%)
Undergraduate students	178(9.0%)
Bachelor degree	1364(68.8%)
Master or above	165(8.3%)
Income (CNY)	
<3,000	225(11.4%)
3,001–6,000	504(25.4%)
6,001–9,000	529(26.7%)
9,001–12,000	391(19.7%)
12,001–18,000	231(11.7%)
>18,000	102(5.1%)
Insurance	
Yes	1929(97.3%)
No	53(2.7%)

CNY = Chinese Yuan.

the associated harm to the human body. The topic of *advertisement* was product information about HPV vaccine from commercial companies.

Study 2

Methods

Sampling

An online survey was conducted in January 2020. We used the online panel of a research company (www.wjx.cn) to recruit participants in China. The company has owned an online panel of more than 2.6 million members in diversified geographical locations and demographics in China. A total of 1,982 Chinese adults completed the survey. Our survey sample generally matches the Chinese population being studied. As shown in Table 2, the respondents were well distributed across age, with the average of 36.9 years old (SD = 10.46; ranging from 18 to 70 years), which is in line with the population's median age of 38.4 (China National Bureau of Statistics, 2020). Also, about half (52.1%) of the sample had a monthly personal income between 3,001 and 9,000 Chinese Yuan (CNY), which accords with the national average of 7,540 CNY (China National Bureau of Statistics, 2020). In terms of gender, 45% of our sample was male respondents, which generally fits with the Chinese population that has a roughly equal gender ratio. It is important to note that we included male participants in this study, because according to China Center for Disease Control and Prevention (2020), both female and male are recommended to take HPV vaccine to help better prevent HPV infection. With regard to health insurance status, a high percentage (97.3%) of our respondents reported having health insurance, which reflects the national data showing that more than 95% of the population is covered by some form of health insurance. In addition, 77% of the respondents in our study received undergraduate degree or above. Although this percentage is slightly higher than the population's education level (54% having college education), it is consistent with the increasing trend of tertiary education in China (The World

Bank, 2020). The study protocol was approved by the Ethics Review Committee at the authors' institutions. Respondents' informed consent was also obtained.

Measurement

HPV vaccine knowledge was measured by 8 dichotomized true-or-false items derived from prior research (Perez et al., 2016). Sample items included "HPV vaccines are most effective if given to people who've never had sex" (true), and "HPV vaccines offer protection against all sexually transmitted infections" (false). Items answered correctly were assigned 1 point while incorrect answers were assigned 0 point. Responses were summed up to represent knowledge about HPV vaccine (M = 5.98, SD = 1.43). A higher score indicated a higher level of HPV vaccine knowledge.

Attitude toward HPV vaccine was operationally defined as one's concern for the safety of HPV vaccine. Three items were drawn from a previous study (Kang & Moneyham, 2010), including "I think the HPV vaccine has not been widely tested," "I am concerned about negative long-term effects of the HPV vaccine," and "I am afraid of side effects of the HPV vaccine" (M = 3.29, SD = .95, Cronbach's alpha = .76). Responses were on a 5-point Likert scale ranging from 1 = strongly disagree to 5 = strongly agree, and then averaged. The higher value represented greater HPV vaccine safety concern.

HPV vaccination intention was measured by three items drawn from prior research (X. Zhang et al., 2017) on a 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree): "I intend to take HPV vaccination in the next 3 months," "I plan to take HPV vaccination in the next 3 months," and "I predict I will take HPV vaccination in the next 3 months" (M = 2.75, SD = .93, Cronbach's alpha = .93). The average of these responses was used for data analysis. The larger the score, the greater intention of HPV vaccination.

Regarding the three types of information acquisition behaviors, namely information seeking, scanning, and discussing, we adapted from the Health Information National Trends Survey (National Cancer Institute, 2021), and its derivative research in the context of China (Liu & Jiang, 2021). Specifically, we borrowed the wordings, but changed the information types based on the topics identified from our Study 1. Given the exploratory nature of these measures, we performed principal component analysis to test for the validity. Results showed that all measures loaded significantly onto their intended latent factors, establishing good construct validity. Also, the percentages of variances supported the construct validity, as a substantial amount of variances in the measurement were explained by the latent constructs.

HPV vaccine information seeking was measured by six questions on a 5-point Likert scale from 1 (not at all) to 5 (very often). Participants were asked to self-report, in the past 12 months, how frequently they have actively searched for the following six types of HPV related topics on social media: HPV vaccine policies (M = 3.20, SD = 1.31), guidance information (M = 3.33, SD = 1.21), advertising (M = 2.72, SD = 1.23), scandals (M = 2.64, SD = 1.28), personal experience (M = 2.74, SD = 1.31), and HPV risks (M = 2.91, SD = 1.24).

HPV vaccine information scanning was measured by asking: "In the past 12 months, how frequently have you encountered [six HPV vaccine topics] on social media?" A 5-point Likert scale was used (from 1 = not at all to 5 = very often). Likewise, the six topics included HPV vaccine policies (*M* = 3.54, *SD* = 1.10), guidance information (*M* = 3.44, *SD* = 1.15), advertising (*M* = 2.99, *SD* = 1.19), scandals (*M* = 2.77, *SD* = 1.29), personal experience (*M* = 2.77, *SD* = 1.28), and HPV risks (*M* = 2.88, *SD* = 1.22).

HPV vaccine information discussing was also measured by a series of questions: "In the past 12 months, how frequently have you discussed [six HPV topics] with others on social media?" A 5-point Likert scale was used (from 1 = not at all to 5 = very often). The six HPV vaccine topics were: HPV vaccine policies (*M* = 3.54, *SD* = 1.10), guidance information (*M* = 3.24, *SD* = 1.28), advertising (*M* = 3.18, *SD* = 1.21), scandals (*M* = 2.62, *SD* = 1.20), personal experience (*M* = 2.65, *SD* = 1.30), and HPV risks (*M* = 2.88, *SD* = 1.22).

Demographic variables, including age, gender (1 = male; 0 = female), education (from 1 = middle school or below to 5 = postgraduate or above), personal monthly income (from 1 = CNY 3,000 or below to 6 = above CNY 18,000), residential status (1 = urban, 0 = rural), and health insurance (1 = yes, 0 = no), were controlled to reduce confounding effects.

Data analysis

Data analysis was conducted with SPSS Version 22. Multivariate linear regression was run to examine how scanning, seeking and discussing the six types of HPV vaccine information are associated with HPV vaccine knowledge, attitude toward HPV vaccine, and HPV vaccine adoption intention, controlling for demographic variables. Also, given the nature of the content-specific measures of information scanning, information seeking, and information discussing, we checked multicollinearity for these variables. The results showed that among the six content-specific items, there was no multicollinearity issue, as all the VIF values were between 1 and 2.

Results

RQ2-4 examined the effects of three types of HPV vaccine information acquisition behaviors on HPV vaccine knowledge, safety concern, and vaccination intention. Regarding the effect on HPV vaccine knowledge, scanning policy information (β = .10, *p* < .01, 95% CI [.052, .205]), and discussing guidance information (β = .07, *p* < .05, 95% CI [.010, .153]) were positively associated with knowledge. Besides, seeking HPV vaccine scandals (β = −.07, *p* < .05, 95% CI [−.152, −.013]) and discussing advertising (β = −.09, *p* < .05, 95% CI [−.176, −.025]) and personal experience (β = −.08, *p* < .05, 95% CI [−.160, −.022]) were negatively associated with HPV vaccine knowledge.

With regard to the influence on HPV vaccine safety concern, both scanning (β = .10, *p* < .05, 95% CI [.030, .116]) and seeking (β = .10, *p* < .05, 95% CI [.028, .126]) HPV vaccine scandal information were positively associated with safety concern. Similarly, both scanning (β = .06, *p* < .05, 95% CI [.002, .092]) and seeking HPV risk information (β = .06, *p* < .05, 95% CI [.001, .093]) increased HPV vaccine safety concern. Whereas, scanning both guidance information (β = −.06, *p* < .05, 95% CI [−.100, −.003]) and personal experience (β = −.09, *p* < .05, 95% CI [−.114, −.022]) reduced HPV vaccine safety concern.

Table 3. Associations between information acquisition and knowledge, attitude, and adoption intention regarding HPV vaccine.

	HPV vaccine knowledge			HPV vaccine safety concern			HPV vaccine adoption intention		
	β	SE	95% CI	β	SE	95% CI	β	SE	95% CI
Age	−.16**	0.003	[−.028, −.016]	−.06*	0.002	[−.010, −.001]	−.05*	0.002	[−.011, −.001]
Gender	−.05*	0.062	[−.258, −.018]	<−.01	0.043	[−.085, .084]	−.06**	0.046	[−.223, −.042]
Education	.08**	0.044	[.047, .216]	−0.02	0.029	[−.082, .030]	0.02	0.034	[−.050, .087]
Income	<.01	0.028	[−.054, .057]	0.03	0.019	[−.016, .057]	.05*	0.02	[.009, .088]
Insurance	0.04	0.225	[−.796, .070]	0.01	0.144	[−.270, .300]	0.01	0.134	[−.205, .319]
Information scanning		ΔR^2 = .04			ΔR^2 = .05			ΔR^2 = .17	
Policy	.10**	0.039	[.052, .205]	−0.05	0.03	[−.107, .012]	−0.03	0.031	[−.100, .025]
Guidance information	0.06	0.04	[−.003, .151]	−.06*	0.025	[−.100, −.003]	−0.01	0.029	[−.068, .048]
Advertising	−0.04	0.035	[−.118, .014]	0.03	0.024	[−.024, .069]	.08**	0.025	[.027, .126]
Scandals	−0.04	0.032	[−.104, .021]	.10*	0.022	[.030, .116]	−0.01	0.025	[−.053, .043]
Personal experience	0.03	0.034	[−.035, .099]	−.09*	0.023	[−.114, −.022]	0.03	0.026	[−.020, .082]
Risk of HPV	−0.05	0.033	[−.122, .005]	.06*	0.022	[.002, .092]	0.01	0.026	[−.034, .063]
Information seeking		ΔR^2 = .01			ΔR^2 = .01			ΔR^2 = .07	
Policy	0.01	0.036	[−.065, .077]	−0.01	0.023	[−.052, .038]	.13**	0.027	[.061, .173]
Guidance information	−0.01	0.038	[−.072, .079]	−0.01	0.024	[−.051, .044]	.07*	0.029	[.017, .133]
Advertising	−0.05	0.039	[−.134, .019]	−0.04	0.023	[−.080, .012]	.09**	0.028	[.026, .140]
Scandals	−.07*	0.036	[−.152, −.013]	.10*	0.025	[.028, .126]	0.02	0.027	[−.037, .070]
Personal experience	−0.02	0.037	[−.091, .054]	0.02	0.025	[−.035, .064]	0.05	0.027	[−.008, .095]
Risk of HPV	0.03	0.036	[−.031, .111]	.06*	0.024	[.001, .093]	0.01	0.026	[−.043, .061]
Information discussing		ΔR^2 = .01			ΔR^2 = .01			ΔR^2 = .02	
Policy	0.05	0.038	[−.025, .126]	−0.03	0.025	[−.071, .029]	0.04	0.028	[−.021, .086]
Guidance information	.07*	0.036	[.010, .153]	−0.01	0.025	[−.055, .040]	.08**	0.027	[.022, .130]
Advertising	−.09*	0.038	[−.176, −.025]	0.02	0.025	[−.037, .060]	.06*	0.028	[.008, .115]
Scandals	−0.02	0.034	[−.087, .048]	0.03	0.024	[−.030, .066]	0.03	0.026	[−.022, .080]
Personal experience	−.08*	0.036	[−.160, −.022]	0.01	0.024	[−.042, .049]	.11**	0.027	[.048, .152]
Risk of HPV	0.01	0.038	[−.058, .091]	0.06	0.025	[−.002, .097]	0.03	0.028	[−.028, .081]
Adjust R²		0.11			0.07			0.3	

* *p* < .05; ** *p* < .01; β = Standardized Beta; SE = Standard Error; CI = Confidence Interval.

As to the impact on vaccination intention, results in Table 3 indicated that scanning (β = .08, p < .01, 95% CI [.027, .126]), seeking (β = .09, p < .01, 95% CI [.026, .140]) and discussing (β = .06, p < .05, 95% CI [.008, .115]) HPV vaccine advertising were all positively associated with HPV vaccine adoption intention. Similarly, seeking (β = .07, p < .05, 95% CI [.017, .133]) and discussing (β = .08, p < .01, 95% CI [.022, .130]) HPV guidance information were also positively related to vaccination intention. Moreover, seeking policy information (β = .13, p < .01, 95% CI [.061, .173]), and discussing personal experience (β = .11, p < .01, 95% CI [.048, .152]) both increased vaccination intention.

Discussion

Following the mixed-methods approach, this study first examined HPV vaccine information on social media in China by using topic modeling. Based on the topics identified from Study 1, we conducted a survey in Study 2 to investigate scanning, seeking, and discussing the HPV vaccine topics on social media and their relationships with users' HPV knowledge and attitude, and vaccination intention. The findings of this study can offer important insights on social media health promotion research and practice.

First, this study demonstrated what prevalent HPV vaccine topics are on social media in China. The results showed that advertisement was the most common topic. This demonstrates the active marketing efforts from the private sector. Although the general publics may find HPV vaccine advertisement useful as it informs them of the prevention of HPV disease, an increasing concern showed that advertisement does not aim to advocate for public goods. Instead, it mainly promotes specific brands that benefit pharmaceutical manufacturers (Manika et al., 2014). Questions have also arisen regarding the ethicality and reliability of pharmaceutical advertising (Leader et al., 2011). In addition, guidance information that introduces HPV vaccine and provides instruction for HPV vaccination also gained public attention. Guidance can help audiences understand new health issues and facilitate health decision-making (Beaudoin & Thorson, 2004). The importance of guidance information is underscored in the diffusion of innovations theory (Rogers, 2010), which states that at the early stage of innovation diffusion, audiences are first exposed to the innovation, but lack information about it. Therefore, to promote people's HPV vaccine adoption, it is crucial to provide guidance information that increases awareness and knowledge. Another common topic was individuals' sharing of their personal experience of taking HPV vaccine. This reflects the interactive nature of social media which supports user-generated content (Moorhead et al., 2013). People learn health knowledge from their online peers who have similar health needs and share their experiences (Korda & Itani, 2013).

Second, we found that different topics or information types exerted dissimilar impacts on health-related outcomes. For example, scandal information decreased knowledge and increased concern for vaccine safety. This result demonstrates the dark side of social media health information. Vaccine scandal information triggers people's health-related fear and anxiety, inhibiting the development of health knowledge

(Clark et al., 2012). This detrimental effect can be particularly salient in the social media environment, where negative news is sometimes exaggerated without rigorous editorial review, and users are often alerted of real-time scandals and spontaneously voice strong negative emotions such as anger or disgust (L. Zhang et al., 2016). In contrast, guidance information can increase HPV vaccine knowledge and enhance vaccination intention. This illustrates the positive impact of social media health communication. Such information contains factual health information that serves as building blocks of knowledge, as it enables people to construct patterns or links between basic elements related to the health issue (Hew & Cheung, 2014). Offering clear instructions can promote audiences' cognitive processing that boosts understanding and critical thinking, resulting in increased knowledge and behavior change (Machand-Martella et al., 2004). The finding that health information can result in both negative and positive outcomes echoes with the key tenet of Longo et al.'s (2001) model, highlighting that within a complicated information environment, different types of healthcare information may affect one's health management and decision-making differently, depending on specific media content, personal context and health issue at hand. Street (2003) also contended that to enhance the effectiveness of interactive media use for health promotion, it is critical to consider message characteristics, including health information topic, among others (e.g., genre of message content, readability and cultural appropriateness). Therefore, to thoroughly understand health information and its impact, close attention should be paid to the nature of messaging content (e.g., information types and topics).

Third, our study also showed that the same health topic may have differential influences, depending on the information acquisition pattern. For example, passively scanning policy information failed to promote vaccination intention, while actively seeking such information enhanced intention. To explain the discrepancy, we need to take into account characteristics of these two information behaviors. Information seeking is associated with individuals' central or systematic information processing, where they actively seek out information and are motivated to carefully scrutinize message content, leading to higher chance of behavior change (Niederdeppe et al., 2007). Information scanning, on the other hand, involves peripheral or heuristic information processing, where individuals encounter information in their normal patterns of media exposure, and minimal effort is made to understand information. Under such circumstance, only limited effects on behavioral intention are likely to manifest (Shim et al., 2006). HPV vaccine is still new to Chinese people, and many of them may be skeptical about the vaccine or worry about potential side effects, resulting in vaccine hesitancy (Wong et al., 2020). Given the complexity of this health issue, information obtained through scanning may not receive in-depth processing, thereby exerting comparatively lower impacts on decision-making and intention. In addition, we found that scanning and seeking guidance information did not affect HPV knowledge. However, discussing such information with others increased knowledge. This result demonstrates that two-way communication (e.g., information discussion) may play a more important role than one-way communication (e.g., information

scanning and seeking) in promoting health learning. One theoretical explanation is discussion-generated elaboration, suggesting that discussion can trigger greater elaboration on information (e.g., making mental connections between the content of conversation and prior experiences), and the information elaboration is critical for the development of knowledge (Eveland, 2004). Besides, discussion partners would provide useful feedback and offer new perspectives, leading to more knowledge gain. Unlike individual information acquisition alone that does not involve information exchange, social media allows online peers to help with each other and collaborate on health care issues (Jiang, 2019). Thus, failing to differentiate information acquisition patterns in this manner, the effect of specific information type would be obscured, with theoretical development waylaid.

Implications for research and practice

This study has several theoretical implications. First, we proposed an analytical model that follows the mixed-method approach. Specifically, in the digital era, to explore new health practice adoption (in this study, HPV vaccine), the first step is understanding what information about the new health practice is disseminated and discussed on social media, by using big data analytics (in this case, topic modeling). However, simply analyzing social media content, by itself, is insufficient to know its potential impact. Therefore, based on the topics identified, it is essential to conduct a survey study to examine how health information is associated with knowledge, attitude and adoption intention. Future research on social media health promotion can utilize our analytical approach. Second, we explored different information types and information acquisition behaviors in the social media setting. A general statement saying online health information is beneficial or detrimental to health would be superficial, lacking more nuanced examination of information behaviors. As shown in our study, the same health topic could have dissimilar influences depending on the specific information acquisition behaviors. Thus, this result extends existing health information models (Longo, 2005; Longo et al., 2001) by focusing on both information type and information use pattern simultaneously, which offers a refined understanding of individuals' health information use. It is also important to note that the original Longo's theory only emphasizes on the one-way communication pattern, such as information scanning and seeking, while our study breaks new ground in adding information discussion, which features two-way communication that is crucial in the context of social media. Future research about social media health information can follow our categorization of information behaviors and specifically investigate what type of information acquired via which pattern can be associated with what health-related outcomes. Without taking into account differences in information acquisition and information type, significant social media use effect might be unclear, hindering theoretical advancement.

Our study also has important practical implications. First, given the positive impact of policy and guidance information on HPV knowledge, future social media campaigns should provide more detailed introduction of the recommended health behavior and offer clearer instruction on what to do and how to do it. For example, health campaign organizations can clearly define the specific health action to take, provide information about how, where, and when to take such action, and clarify the positive effects to be expected. Furthermore, providing training or guidance in performing an action will be useful as well. Second, the results that information about HVP vaccine scandals decreased knowledge and increased safety concern suggest the urgent need to cope with the challenge of fake or counterfeit vaccine. The government should establish a series of mechanisms to promote the production and delivery of quality vaccine, and roll out strict regulations to punish violations of vaccine safety. On social media, government agencies can proactively disseminate information about such encouraging actions to maintain high vaccine safety standards, which will enhance transparency and publics' trust toward government, and increase their confidence and willingness of HPV vaccine uptake.

Limitations and directions for future research

Several limitations should be noted. First, in Study 1, we only collected data from Weibo. Although Weibo is one of the most popular social networking sites in China, other social media is also important to examine. For example, WeChat has 1 billion active users. Different from Weibo, which is more open and visible, WeChat is more private and relationship-focused. Given the different technological characteristics, future research should include a greater variety of social media. Second, three approaches can be used to extract information from a large volume of unstructured texts: dictionary matching, supervised machine learning, and unsupervised machine learning (Nelson et al., 2018). The current study adopted the first approach. Although this approach has been widely used and considered efficient, it may not be the best strategy in terms of identifying targeting posts from the full dataset. King et al. (2017) proposed a computer-assisted statistical approach to identify targeting texts based on machine learning and human coding, which has been shown to have higher precision in text discovery. More rigorous work on the preprocessing of texts needs to be conducted in the future. Third, Study 2 used online survey. This nonrandom sample makes it difficult to generalize our findings to the larger population. Also, with the cross-sectional survey design, causality can only be inferred. Future research should ideally use nationally representative samples and follow a longitudinal design. Fourth, in this study, we measured vaccination intention rather than the actual behavior, because the HPV vaccine was only recently approved in China. However, we acknowledge that despite the low overall uptake of HPV vaccination, there might be a small portion of participants who have already got vaccinated. Thus, future research should include the actual HPV

vaccine uptake, which is also of high relevance and importance in health communication. Fifth, given the relatively large sample size of this study, it is easy to obtain significant results due to excessively high statistical power. Future research should use sampling techniques and perform power analysis to estimate ideal sample size for statistically sound results. Finally, our sample has a higher education level, compared to the general population in China. This could lead to biased results, as younger people have more often social media use and better digital literacy. Thus, future research needs to recruit participants with a greater diversity of age, particularly older adults.

Notes

1. The irrelevant posts are those whose subject matter is not mainly about HPV or HPV vaccine. People may simply insert terms or hashtags, such as "HPV" or "HPV vaccination" in their posts, because they are hot topics at the time. In this manner, the posts can attract more attention, increasing the possibility of being seen by more netizens. For example, there was a post introducing termite mushroom, but it contained a series of hashtags that were popular topics at the time, including HPV vaccine. For highly commercialized social media platforms such as Weibo, this is a common practice, especially considering that many bloggers rely on visibility or exposure for daily account operation. Another type of irrelevant posts was headline news in which HPV vaccine was only a small part. Although there might be some content related to HPV vaccine, the major part of these posts was about another issue. Also, irrelevant posts may be created by social bots as well. Therefore, for the purpose of the current study, irrelevant posts were filtered because they can affect the accuracy and efficiency of topic modeling.
2. A Chinese term expressing encouragement, incitement, or support to others.
3. The name of a commercial company offering HPV vaccination.

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Ethics statement

Survey respondents provided informed consent. The study protocol was approved by the Department Ethics Review Committee at National University of Singapore.

Authors contribution

Dr. Shaohai Jiang and Dr. Pianpian Wang contributed equally to this work.

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