6-20-2018

Using Computational Methods and Experimentation to Understand the Persuasiveness of Vaccine Messages

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In the digital age, true and false information can influence health-related decisions differently. It is important to monitor the dissemination of misinformation, understand public interests and develop persuasive messages. Two studies were conducted in order to meet these goals. Study 1 used computational methods to explore topic evolution and popularity in vaccine-related online messages. Topic modeling identified 14 topics in pro-vaccine messages (PVMs) and 12 topics in anti-vaccine messages (AVMs). PVMs that used personal stories received the highest number of shares, reactions, and comments. Pure scientific knowledge received the least attention. The most frequently appearing topic in AVMs was about child death. AVMs that discussed flu shots and government conspiracy were the most popular. Since 2016, even though more PVMs appeared online, AVMs were more popular and the comparative popularity of AVMs increased fast. AVMs that discussed vaccine damage were increasingly popular. Newly-emerged anti-vaccine topics (e.g. false rumors of CDC conspiracy) should be noted.

Based on Study 1's results, Study 2 designed four PVMs and tested if these messages could increase HPV vaccine acceptability among parents who had not vaccinated their children. A total of 301 parents participated in an online experiment. SEM was used to analyze emotional and cognitive responses after the intervention. Results revealed that only the pro-organization message with low levels of emotions could increase vaccine acceptability. Anti-organization

messages had no effect on the outcome. Political views and gender of parents could influence vaccine-related cognitive responses and eventually affected vaccine acceptability. Implications for message design were provided.

Keywords: Misinformation, vaccine, emotion, topic evolution, popularity

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B.A., Nanjing University, 2009

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A Dissertation

Submitted in Partial Fulfillment of the

Requirements for the Degree of

Doctor of Philosophy

at the

University of Connecticut

2018

APPROVAL PAGE

Doctor of Philosophy Dissertation

Using Computational Methods and Experimentation to

Understand the Persuasiveness of Vaccine Messages

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2018

Acknowledgements

First and foremost, I wish to thank my advisor, Dr. Ross Buck, for his tremendous support for my learning and research. My committee guided me through all these years. Thank you to Dr. Leslie Snyder and Dr. Mark A. Hamilton for your patience in advancing my understanding of research design, research methods and statistical analyses. Many thanks to Dr. Saras Bellur and Dr. David Atkin for serving as readers of my dissertation. I appreciate their feedback on my work. I am more than fortunate to be supervised by Dr. Kenneth A. Lachlan, who involved me into his research projects, shared valuable experience, and inspired me with his work. I would also like to thank Dr. Carolyn Lin for including me in her projects. I appreciate the opportunity to sit in on Dr. Anne Oeldorf-Hirsch, Dr. Stephan Stifano, and Dr. John Christensen's classes to learn about teaching.

In addition, I am grateful for having my cohorts in this department. Special thanks go to Suji, Christina, Alex, Adam, and Yi.

I have an amazing family in China. Their support has been unconditional all these years.

Finally, this dissertation is dedicated to Hao, who I cannot thank enough.

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Chapter 1 Introduction

1.1 Health Misinformation

Today people can find health information online (Viswanath, 2005). According to the Pew Research Center, more than 70% of U.S. internet users search for health information online, and 1 in 3 U.S. adults try to diagnose a medical condition online (Fox & Duggan, 2013). However, the Internet contains false or fake information that can lead to confusion and frustration as well as resistance to professional recommendations from doctors and scientists (Arora, Hesse, Rimer, & Viswanath, et al., 2008; Nagler, 2014). In addition, misinformation can influence attitudes and behaviors adversely and eventually harm public health (Eysenbach, Powell, Kuss, & Sa, 2002).

Misinformation or false information refers to information that falsely or inaccurately represents scientific fact and contemporaneous scientific consensus. It is important to note that unverified information cannot be regarded as misinformation because unverified information may also be true. Health misinformation, which is against established medical understanding (Ghenai, 2017; Tan, Lee, & Chae, 2015), has been an increasingly important topic in health studies.

In the digital age, health misinformation can be distributed broadly to reach a large population in a short time. For example, during the Ebola outbreak in 2014, Twitter contained more medical misinformation than correct information (Oyeyemi, Gabarron, & Wynn, 2014). Misinformation could reach a much larger number of potential readers than true information (Oyeyemi, Gabarron, & Wynn, 2014). Health misinformation can lead to the confusion and

uncertainty about the scientific evidence-based information as well as cause panic, the delay of treatment and a widespread epidemic (Merino, 2014; Oyeyemi, Gabarron, &Wynn, 2014).

However, efforts to counteract misinformation, such as using repeated warnings and retractions, are not as effective as expected. Interventions to correct misinformation may backfire and increase misconceptions (Nyhan, Reifler, Richey, & Freed, 2014). Thus, it is difficult to combat misinformation once it is spread widely (Lewandowsky, Ecker, Seifert, Schwarz, & Cook, 2012).

1.2 Vaccine Misinformation

Vaccination is one of the greatest achievements in public health and biomedical science. It largely reduces morbidity and mortality of many diseases and saves about three million lives per year in the world (World Health Organization, 2013). However, a growing number of people seek non-medical exemptions for their children (Omer, Richards, Ward, & Bednarczyk, 2012), which has led to outbreaks of vaccine-preventable diseases such as measles, mumps and whooping cough (Majumder, Cohn, Mekaru, Huston, & Brownstein, 2015; Centers for Disease Control and Prevention, 2012).

Vaccine-related misinformation, which is often spread online by anti-vaccine groups (Davies, Chapman, & Leask, 2002), may be the most widely disseminated health-related misinformation (Zimmerman, Wolfe, Fox, & Fox, et al., 2005). Anti-vaccine content exists in many of the top Google search results using “vaccine” as the keyword (Davies, Chapman, & Leask, 2002; Kata, 2010; Wolfe & Sharp, 2005). Anti-vaccine articles are more likely to be shared, commented and reacted online than pro-vaccine messages (Xu & Guo, 2018). Online anti-vaccine messages can lead parents to question the safety of vaccine, distrust health

professionals, and seek non-medical vaccine exemptions (Jones, Omer, Bednarczyk & Halsey, et al., 2012; Salmon, Moulton, Omer & deHart, et al., 2005).

According to previous studies, two main factors lead to the persuasiveness and popularity of vaccine misinformation: emotional content within vaccine messages and distrust of public health agencies. Xu & Guo have found that the headlines of online anti-vaccine articles contain significantly more emotion words than pro-vaccine headlines. In addition, anti-vaccine headlines are more likely to use words related to fear, anger, and sadness (2018). By including emotional narratives such as stories about children who died from vaccines, vaccine misinformation can increase risk perceptions and discourage vaccine intentions (Betsch, Ulshofer, Renkewitz, & Betsch, 2011; Kata, 2010; 2012).

The second strategy that vaccine misinformation often uses is discrediting professional health organizations by creating conspiracy theories. Anti-vaccine headlines are significantly more likely to include words that foster distrust of public health organizations (Xu & Guo, 2018). Anti-vaccine websites often contain conspiracy theories about how governments, public health organizations, and companies hide the side effects of vaccines and promote vaccines only for profit (Kata, 2012). Conspiracy theories can lead to the distrust of scientific evidence (Lewandowsky, Oberauer, & Gignac, 2013), which in the end reduce the intention to get vaccinated (Jolley & Douglas, 2014).

1.3 HPV Vaccine

HPV (Human papilloma virus) is the most common sexually transmitted disease in the U.S. About half of sexually active Americans are infected by HPV virus. HPV infection is the leading cause of cervical cancer and genital warts. In order to prevent HPV, HPV vaccines are recommended by CDC for both teenage girls and boys (Meites, Kempe, & Markowitz, 2016).

Since parents' consent is crucial to get HPV vaccines for their children, parents' vaccine acceptability is targeted by most health program designers and researchers (Brewer & Fazekas, 2007). However, about 2 in 5 young adolescents have not received their first dose of HPV vaccine, and 60% of teens do not complete the vaccination series (Walker, Elam-Evans, Singleton, Yankey, et al., 2017). Anti-HPV vaccine articles may impact parents' decisions negatively. Anti-HPV vaccine articles often claim that natural infection can prevent HPV virus reinfection and reduce the risk of HPV caused cancer (e.g. Borgan & Ji, 2014; Ji, 2018). One of these articles has received more than 110,000 shares, comments, and reactions online within 3 months since it was first published. It is possible that these statements can lead many viewers to believe in the benefit of natural infection and refuse HPV vaccine. Therefore, it is necessary to raise the awareness of HPV vaccine and encourage parents to vaccinate their children especially among those who have not vaccinated their children.

In conclusion, it is critical for researchers and practitioners to monitor the dissemination of misinformation, understand public interests and concerns, as well as develop effective persuasive messages. Two studies, which focused on vaccine information and misinformation, were conducted in order to meet these goals. Study 1 used computational methods (text mining and topic modeling) to analyze the content, topic evolution and online popularity in pro- and anti- vaccine information. Based on study 1's findings and implications, study 2 designed four pro-vaccine messages and used an online experiment to test if these messages could decrease HPV vaccine unacceptability among parents who had not vaccinated their children. The methods and findings can be applied to other health topics and other research domains (e.g. fake political news).

Study 1

Chapter 2 Theories and Research Questions

2.1 Narratives and the Transportation-Imagery Model

Over the past decade, the use of narrative information in health message design has been increasingly popular. Commonly-used forms of narrative information include stories and testimonials. Narrative information often contains characters, storyline, and scene, either constructed or really experienced (Hinyard & Kreuter, 2007).

The transportation-imagery model can explain the persuasive power of narrative communication. According to the model, viewers who are exposed to narrative information can be "transported" into the story by their feelings and imagination. Transported viewers tend to identify with the characters and have strong emotional responses to the stories. Thus, they may be more likely to believe the stories and less likely to question the narratives, which lead to potential attitudes or behavior changes (Green & Brock, 2000, 2002).

2.2 Health and Vaccine Narratives

A recent meta-analysis indicates that narratives can lead to desired health outcomes especially in detection and prevention behaviors (Shen, Sheer & Li, 2015). For example, narrative messages can successfully reduce unhealthy behaviors, such as smoking (Kim, Bigman, Leader, & Lerman, et al. 2012) and using tanning beds (Greene & Brinn, 2003). Narratives have also been used to effectively promote desired health behaviors, such as Pap tests (Love, Mouttapa, & Tanjasiri, 2009) and mammography (Kreuter, Green, Cappella, & Slater, et al., 2010).

Within the specific context of vaccination, studies have found that narratives can

effectively communicate the importance of vaccines (Murphy, Frank, Chatterjee & Baezconde-Garbanati, 2013). Narratives about vaccine danger can increase risk perception of vaccine even when participants are well-informed about vaccine side effects (Betsch, Renkewitz, & Haase, 2013; Betsch, Ulshofer, Renkewitz, & Betsch, 2011).

2.3 Research Questions

Most studies of narratives use experimental settings where participants experience a single exposure to several made-up narrative messages. However, this hardly reflects actual health campaigns that people encounter in everyday life (Shen, Sheer, & Li, 2015). There remains a need to examine whether existing vaccine-related campaigns use narratives, and, in turn, whether narratives influence messages' popularity and impact.

In addition, online content and Google's top search results change fast. Vaccine messages may apply new persuasive strategies (Moran, Lucas, Everhart, & Morgan, et al. 2016; Xu & Guo, 2018). Thus, internet users are likely to be exposed to different content and persuasion techniques over time. Their viewing experience and interaction with the content may also change over time. However, to my knowledge, no studies have investigated the evolution of pro- and anti-vaccine topics as well as their effects on viewers' behaviors. Understanding the shifts in vaccine-related topics and their popularity over time can help researchers and practitioners develop effective persuasive strategies to promote vaccines. Given limited past research, the present study asks the following:

RQ1: What are the most frequently used words in pro- and anti-vaccine online articles?

RQ2: What are the most commonly appearing pro- and anti-vaccine topics online?

RQ3: What pro- and anti-vaccine topics receive the most online popularity?

RQ4: How have the topics in pro- and anti-vaccine online articles evolved over time?

RQ5: How have people's interests in different vaccine topics evolved over time?

Chapter 3 Methods

3.1 Selection of Webpages

Since Google is the most widely and frequently used search engine (comScore, 2016), it was chosen to obtain vaccine-related webpages. The present study used the similar search strategy in Moran's study (Moran, et al. 2016), which searched 12 combinations of terms capturing the effects of vaccines in Google respectively. These terms included, vaccine+danger, vaccine+harm, vaccine+secret, vaccine+death, vaccine+injury, vaccine+hidden, vaccine+fact, vaccine+statistics, vaccine+benefit, vaccine+important, vaccine+reason, vaccine+information. The first 200 results of each search term were included in the current study on May 5, 2017. One article could be captured multiple times by the different search terms.

After duplication check, 2,067 unique articles' URLs were put into an Excel sheet. Two trained coders checked if each article met the criteria to be included in the final analysis. Articles were included if they (a) were active links; (b) focused on human vaccines; (c) indicated that people should or should not get vaccinated; (d) discussed benefits/risks of vaccines. Articles were excluded if they (a) were not written in English; (b) only contained a video without any text description; (c) were listserv, newsgroup or discussion board pages; (d) required downloading. After excluding those that did not meet the requirements, coders assigned the article into either pro- or anti-vaccine articles (intraclass correlation = .92) and solved disagreements by discussion. In the end, 541 pro-vaccine articles and 382 anti-vaccine articles were included in the final analysis.

3.2 Coding and Operational Definitions

Publication Date. Day, month, and year when an article was first published online were obtained.

Online Popularity. SharedCount (https://www.sharedcount.com) was used to reveal the number of times that an article was shared, reacted, and commented on Facebook, Google+, LinkedIn, Pinterest, and StumbleUpon. Online popularity was measured using two indicators. The **Sum of Topic Popularity (N_{sum})** consisted of the total number of the shares, reactions, and comments across all articles within a topic. **Average Topic Popularity ($N_{average}$)** was computed from the sum of topic polarity divided by the number of articles belonging to the topic ($N_{article}$).

3.3 Topic Modeling

Previous studies often use human coders to manually categorize anti-vaccine websites into several topics. For example, Kata (2010) categorized 150 anti-vaccine articles into eight groups (e.g. safety & effectiveness, alternative medicine, emotive appeals, etc.). Bean (2011) grouped 25 sites into four subcategories (e.g. civil liberties, conspiracy theories, etc.). However, content analysis that manually categorizes topics can have low reliability since coders often need to use intuition to group contents (Günther & Domahidi, 2017). Topic modeling, which relies on machine learning algorithms to fully automatically categorize the emergence of topics in a research field, can be an alternative.

Topic modeling is based on Bayes' hierarchical model. It can discover patterns of words and group documents with similar patterns from unstructured data (Blei, Ng, & Jordan, 2003; Blei & Lafferty, 2009). One of the simplest and most popular method of topic modeling is the *Latent Dirichlet Allocation* (LDA) model. In LDA, "a topic is defined to be a distribution over a fixed vocabulary of terms (Blei & Lafferty, 2009, pp. 73). LDA estimates the probability

distribution of topics on each word, the importance of words to each topic, and the prevalence of words in each document. Based on all the information, the algorithm estimates probabilities of topics on each documents. LDA has been validated by many studies (e.g. Griffiths & Steyvers, 2004; Cao, Xia, Li, & Zhang, 2009; Arun, Suresh, Madhavan, & Murty, 2010; Deveaud, SanJuan, & Bellot, 2014). For example, using 2,620 abstracts published in Proceedings of the National Academy of Sciences, Griffiths, and Steyvers (2004) discovered a strong association between topics classified by topic modeling algorithm and paper categories selected by authors when they submitted the paper.

In the health domain, topic modeling has been predominately used to study public discussion and opinion about certain health topics on social media and other online platform (e.g. HPV vaccine in Surian, Nguyen, Kennedy, Johnson, et al., 2016; e-cigarette in Zhan, Liu, Li, Leischow, et al., 2017; ebola in Odlum & Yoon, 2015; smoking among cancer survivors in Westmaas, McDonald, & Portier, 2017). These studies successfully monitored the dissemination of health-related information as well as analyzed public knowledge, emotional and cognitive responses, and behaviors. In the present study, topic modeling is used to identify the topics in pro- and anti-vaccine online articles based on their full text.

3.4 Analysis

First, word frequencies in pro- and anti-vaccine messages were calculated. Function words (e.g. “the”, “of”, etc.) were deleted before analysis. Second, LDA topic modeling was used to generate topics of pro- and anti-vaccine messages. Next, online popularity of topics in pro- and anti-vaccine messages were compared. Finally, the locally weighted scatterplot smoothing (LOESS) method (Cleveland, 1979) was used to create smooth lines of online

popularity over a decade from April 2007 to April 2017. LOESS is a non-parametric method and robust to outliers.

Chapter 4 Results

4.1 Word Frequency

The final analysis included 508,571 words from 541 pro-vaccine messages (Mdn=669) and 843,805 words from 382 anti-vaccine messages (Mdn=1,096).

RQ1 asked the most frequently used words in pro- and anti-vaccine online articles. Wordclouds were created to visualize the most common words in pro- and anti-vaccine messages (See Figure 1 & 2). The font size represents the relative frequency that a certain word was used in pro- or anti-vaccine messages. Two of the biggest words used in both pro- and anti-vaccine messages were *children* and *disease,* which mean that these two words were the most frequently used words in both messages. Besides, pro- or anti-vaccine messages both frequently used *health, death,* etc. Pro-vaccine messages used a lot of *immune, prevent, cancer, protect,* and *risk.* Anti-vaccine messages often used *autism, doctor,* and *studies*.

4.2 Topics and Online Popularity

Topic modeling identified 14 topics in pro-vaccine messages and 12 topics in anti-vaccine messages. Results also displayed top terms in each topic. Based on these terms, a name was assigned to each topic to facilitate readers' understanding. Table 1 & 2 presented four of the most representative terms of each topic and the names that were assigned to each topic. For example, top terms in one of pro-vaccine topics included *HPV, cancer, women,* and *cervix*.

These terms implied that this topic mainly discussed HPV vaccine. Thus, the name assigned to this topic was *HPV Vaccine*. Pro- and anti-vaccine messages shared some similar topics, such as HPV vaccine, flu shot, and adverse case. They both used personal stories and studies to persuade viewers.

RQ2 and RQ3 asked about the most common and popular topics in pro- and anti-vaccine online articles. Results indicate that the most frequently discussed pro-vaccine topic was flu shot ($N_{article}$=82). The least frequently discussed pro-vaccine topic was the one that reviewed the development of vaccines ($N_{article}$=10). The topic that used personal story to support vaccines received the highest number of shares, reactions, and comments (N_{sum}=1,240,291) even though only 37 articles fell into this topic. On average, each message was shared, commented, and reacted 33,521 times online. In contrast, people cared less about vaccine guidelines. The average popularity per message was only 116.

Regarding anti-vaccine topics, the most frequently appearing topic was child death ($N_{article}$=109). Articles discussing polio vaccine ($N_{article}$=4) and anti-vaccine study ($N_{article}$=5) were rarely seen online. Child death was also the most popular anti-vaccine topic online in terms of the sum of popularity (N_{sum}=857,570). Considering the average popularity of each article, flu shot ($N_{average}$=16,879), government conspiracy ($N_{average}$=11,286), and personal story (topic 5, $N_{average}$=8,791) topics received the most attention online. Polio vaccine danger was the least popular topic ($N_{average}$=340).

4.3 Topics and Popularity Over Time

The next step is to consider how topics in pro- and anti-vaccine messages and their online popularity have changed over the last 10 years in order to answer RQ4 and RQ5. Figure 3 compares the *number* of pro- and anti-vaccine messages from top Google search results. Since

April 2015, and especially after 2016, more pro-vaccine messages appeared in top Google search results than anti-vaccine messages. However, as illustrated in Figure 4, since April 2015, anti-vaccine messages were more *popular* online than pro-vaccine messages. The comparative popularity of anti-vaccine messages increased fast. The online popularity of pro-vaccine messages peaked around the end of 2013, after which the number of comments, reposts, and likes decreased dramatically.

Figure 5 displays the trends in pro- vaccine topic and their online popularity since April 2007, plotting time on the x-axis and the topic's popularity on the y-axis. It is important to note that the scales on the y-axis are different across different topics. Dots that are far away from the line are the outliers. Topics that emerged more in and after 2011 included personal story, vaccine development, vaccines for children, and vaccine studies. In contrast, articles that focused on vaccine benefit gradually lost interests among viewers.

Trends in anti-vaccine topic articles and popularity since April 2007 appear in Figure 6. Vaccine damage articles witnessed a significant increase in popularity since 2016, as did polio vaccine. However, only 4 articles fell into this topic. Articles that focused on injury compensation, CDC conspiracy, polio vaccine, and anti-vaccine study appeared after 2011. Vaccine injury compensation gradually lost popularity among readers. Online popularity of personal story and government conspiracy peaked between the end of 2014 and the beginning of 2015.

Chapter 5 Discussion

This is the first study to explore topics and online popularity trends in pro- and anti-vaccine messages over time. It also shows that topic modeling can be used to effectively quantify

and visualize topic changes across large datasets. Its methods and findings can be applied to other health topics and research area.

5.1 Narratives and Topic Popularity

Both pro- and anti-vaccine messages use narratives, such as personal stories and testimonials, to persuade viewers. Anti-vaccine narratives usually include personal stories that children were hurt or killed by vaccines and their parents were devastated (Kata, 2010, 2012). Anti-vaccine messages also include doctors' testimonies about the danger of vaccines. These anti-vaccine messages often claim that these doctors are well-educated, experienced, and serve as members of some organizations. They stop and delay vaccines because of their research and observations of vaccine danger (e.g. Edwards, 2015). In contrast, pro-vaccine narratives often include stories about parents feeling guilty because their unvaccinated children were killed by vaccine-preventable disease (e.g. Mulroy, 2017). The results of the present study imply that true information with narratives can reach a larger population than messages mainly including scientific knowledge (e.g. guidelines and development of vaccines). The fact that more people are exposed to and are interested in narratives increases the possibility that narratives can change related attitudes and behaviors. This finding is useful for message designers. Currently, not many pro-vaccine articles use narratives. Personal stories should be included more often in pro-vaccine messages in order to attract the audience.

5.2 Misinformation, Uncertainties, and Emotions

Overall, there are more pro-vaccine articles than anti-vaccine articles on the Internet. However, since April 2015, these pro-vaccine articles received less attention and reach fewer people than anti-vaccine articles. According to Del Vicario and colleagues' study (2016) which examined the dissemination of true and false political stories on Facebook, true information only

gains interest shortly after it is published and loses popularity among viewers quickly. In contrast, fake information can remain popular for a much longer time. Thus, we may predict that anti-vaccine articles that already gained much attention since April 2015 may continue to be spread quickly.

The present study implies that misinformation can be increasingly popular during times of uncertainty. For example, since 2016, the advantage of anti-vaccine messages' online popularity over pro- vaccine is increasing. In addition, the number of anti-vaccine articles about vaccine damage increased drastically since 2016. A possibility is that statements by the current President of the U.S., in which he links autism to vaccine, questions vaccine safety, and distrusts doctors, encourage the anti-vaccine movement and result in public confusion (Entis, 2017), which may lead to more misinformation about vaccine damage and the rising popularity of anti-vaccine messages.

Another example is the fact that two anti-vaccine topics, personal stories and government conspiracy, received the most shares, comments and reactions online from the end of 2014 to the beginning of 2015. During this period of time, a measles outbreak took place in Disney theme parks in California, causing 125 measles cases. Among the California patients, 45% were unvaccinated (Zipprich, Winter, Hacker, Xia, et al., 2015). This event soon became a national story and led to many debates (Aylesworth-Spink, 2016). Anti-vaccine groups regarded this outbreak as a proof of the ineffectiveness of vaccines since the majority of victims were vaccinated. They claimed that the outbreak was more likely to be caused by a recently vaccinated individual and public health organizations should not be trusted (e.g. Huff, 2015). In this time of uncertainty, the online popularity of pro-vaccine messages continued to decrease while anti-vaccine messages were increasingly popular and overpowered pro-vaccine messages in the end.

People tend to rely on emotions to make decisions when they experience uncertainty (Faraji-Rad & Pham, 2017). Therefore, people may be more inclined to read or even trust misinformation when they are confused and anxious. Future studies are expected to examine if uncertainty can lead people to seek and trust misinformation.

5.3 Refutational Two-Sided Messages

Scientific and true information often present disagreements and limitations (Jensen, 2008; Dixon & Clarke, 2013a), which in persuasion is referred to as a two-sided message (Hunt & Smith, 1987). For example, some of the pro-vaccine topics discuss negative points such as side effects, parents' hesitancy, anti-vaccine movement and adverse case. However, presenting negative information in order to promote a behavior may not be effective. Dixon and Clarke (2013b) found that participants who read articles that present disagreements on autism-vaccine link were more uncertain about vaccines safety and were less likely to vaccinate their children.

A meta-analysis reveals that nonadvertising topics, such as topics that promote vaccines, can be more persuasive when they use refutational two-sided messages than nonrefutational two-sided messages and one-sided messages (Keefe, 1999). This finding indicates that messages can be more persuasive when they directly attack opposing arguments than when they only acknowledge the opposing side or do not include any opposing statements. This result can explain the popularity of anti-vaccine messages. Many anti-vaccine topics directly attack organizations that support vaccines while some pro-vaccine topics only acknowledge the opposing statements by admitting that vaccines have side effects. Future research can explore if pro-vaccine messages, which directly attack anti-vaccine groups followed by explaining vaccine side effects, can be popular and convincing.

5.4 Public Interest, Needs, and Education

The current study reveals that topic modeling can be a powerful tool for health practitioners to capture the changes in the public interests. For example, as the public gradually loses interest in articles about vaccine benefits, message designers can avoid creating more articles that focus purely on vaccine benefits. Since personal stories are increasingly popular, message designers can create more interventions inviting parents to share their own experience.

This study also shows that topic modeling can be used to monitor the dissemination of misinformation. Newly developed anti-vaccine topics bring pro-vaccine message designers new challenges. It is important for health educators to monitor the changes of hot topics in health misinformation in order to know the targeted areas to disseminate true information. For example, since anti-vaccine groups started to use CDC conspiracy and anti-vaccine studies to persuade viewers, health educators should address public's knowledge gap by explaining problems in anti-vaccine research, as well as increase the public's trust of CDC and other public health organizations.

5.5 Limitations and Conclusion

Before drawing the conclusion, it is important to note that this study only examines the popularity of vaccine-related articles on and before April 2017. Some articles may gain more shares, comments, and reactions in the future. In addition, Facebook stories, twitter posts, and videos were not included in the present study. Since online popularity of articles may vary in different social media platforms (Piotrkowicz, Dimitrova, Otterbacher & Markert, 2017), future studies should explore vaccine-related contents and popularity on other platforms. Finally, articles that contained both narrative elements and scientific knowledge were assigned into one topic automatically by machine learning algorithms. It is possible that a combination of both

contents can be more popular than articles that only use personal stories or scientific information. Future studies can use human coders to manually examine and compare detailed strategies used in the most popular vaccine topics, as well as investigate if a combination of techniques used in vaccine messages can lead to the highest level of online popularity.

In sum, the present study uses topic modeling to categorize pro- and anti-vaccine online articles' topics automatically. It shows that certain topics can be more popular online and can potentially reach a larger population. It also reveals the evolution of vaccine-related topics and public's interest. These findings can help researchers design effective interventions as well as develop programs to track and combat health misinformation.

Study 2

Chapter 6 Implications of Study 1 Results

Study 1 has several implications for message design. First, it indicates that pro- vaccine messages should include more narratives. According to previous studies, narrative messages can be influential if they contain emotional contents that can successfully evoke strong emotional responses among viewers (Hinyard & Kreuter, 2007). Second, anti-organization messages that undermine the credibility of an organization can attract viewers' attention and may be persuasive. Thus, study 2 includes several newly-designed pro-vaccine messages that contain different levels of emotional contents. These messages either emphasize or undermine the credibility of an organization. This study aims to use an online experiment to test if these messages are able to reduce negative thoughts about vaccines and vaccine unacceptability among

parents who have not vaccinated their children. Even though this study only focuses on HPV vaccine, the results and implications can be useful for other health messages design.

Chapter 7 Hypotheses

Previous studies have found that females are more likely to know HPV and HPV vaccine than males (Reimer, Schommer, Houlihan, & Gerrard, 2014). One possible reason is that when HPV vaccine was first approved, it was only approved for, testing and marketing to females (Daley, Vamos, Thompson, Zimet, et al., 2017). Parents of girls are more likely to receive a recommendation from a health provider to vaccinate their children than parents of boys, and boys are less likely to be vaccinated (Lindley, Jeyarajah, Yankey, Curtis, et al., 2016). Parents' gender also influences their perceptions of HPV and HPV vaccine. Mothers are more likely to be responsible for their children's health than fathers (Lauritzen, 1997). Thus, mothers may have a stronger opinion– either accept or refuse HPV vaccine. Based on previous literatures, it is hypothesized that,

H1: Mothers have higher levels of preexisting a) HPV knowledge, b) safety concern, c) perceived severity, d) perceived susceptibility, e) efficacy, and f) HPV vaccine unacceptability than fathers.

H2: Parents who have at least one girl have higher levels of preexisting a) HPV knowledge, b) safety concern, c) perceived severity, d) perceived susceptibility, and e) efficacy than parents who only have boys.

H3: Parents who only have boys have higher levels of preexisting HPV vaccine unacceptability than parents who have at least one girl.

Even though HPV vaccine has been proved to be safe and effective, conservative groups worry about vaccine safety and side effects (Gostin, 2011). President Trump's statement that links vaccine to autism encourages anti-vaccine movement and may lead his followers to distrust HPV vaccine (Entis, 2017). Since people that have different political views may have different levels of safety concerns, they may also be different in other cognitive perceptions of HPV and HPV vaccine. Thus, we have the following hypotheses,

H4: People who are more conservative have higher levels of preexisting a) safety concerns and b) HPV vaccine unacceptability than people who are more liberal.

H5: People who are more liberal have higher levels of preexisting a) HPV knowledge, b) perceived severity, c) perceived susceptibility, and d) efficacy than people who are more conservative.

Emotions expressed in and evoked by messages have been studied in health domain for more than 60 years (Nabi, 2002). Message makers consciously use words, images, music, and other forms of communication to arouse emotional responses from viewers in order to make messages more appealing and memorable (Mogaji & Wright, 2016). Most of these studies have proved that emotion is at least as effective as cognition in decision-making process. For example, a recent meta-analysis suggests that cognitive and emotional responses to health messages are not significantly different in their abilities to predict desired health attitudes and behaviors. Emotions have small average correlations with desired intentions ($r=0.25$) and behavior ($r=0.18$) (Xu & Guo, 2018). Based on previous studies, we hypothesize that,

H6: Messages that express stronger emotions are more likely to reduce HPV vaccine unacceptability than messages that do not contain emotion words.

The credibility and competency of sources influence people's willingness to follow their advice (Hovland & Weiss, 1951). Sources with a good reputation are more likely to induce ideal attitudes and behaviors than sources with low credibility (Haase, Betsch & Renkewitz, 2015). Thus, some messages tend to emphasize the credibility of sources to increase their persuasiveness. For example, pro-vaccine messages may cite well-known doctors from top research institute to make their messages convincing. Another strategy is to undermine the credibility of others in order to decrease trust in others' advertising. For example, pro-vaccine messages discredit anti-vaccine scholars to prohibit readers from trusting anti-vaccine messages (e.g., Forster, 2017). This strategy has been proved to be effective. The Florida Tobacco Control Program launched the "truth" countermarketing campaign to undermine credibility of the tobacco industry. By revealing the fact that tobacco companies intentionally denied cigarettes' negative effect, the "truth" campaign successfully reduced smoking among Florida young people (Niederdeppe, Farrelly, & Haviland, 2004). Previous studies have not examined which one of the two messages, pro-organization messages that emphasize the credibility of an organization or anti-organization messages that undermine the credibility of an organization, are more persuasive. Study 1 implies that undermining the credibility of an organization may be more likely to attract attention, which may lead to potential decision changes. Thus, it can be hypothesized that,

H7: Messages that attack the credibility of an anti-vaccine organization are more likely to reduce HPV vaccine unacceptability than messages that emphasize the credibility of a pro-vaccine organization.

Chapter 8 Theories and Process Model

Many persuasion theories aim to explain the relationship between emotions and cognitive evaluations in decision-making and behavioral changes. These theories all assume that judgements and decisions follow two paths: cognitive analyses and spontaneous feelings. Examples include *the extended parallel process model* (Witte, 1992) which examines how fear appeal messages evoke fear and influence decisions; *appraisal-tendency framework* (Lerner & Keltner, 2000; 2001) which links discrete emotions to specific judgment outcomes. *The risk-as-feelings hypothesis* (RaF) is proposed to explain how emotions and cognitive assessments after being exposed to a risk situation can influence risk perceptions, judgements and decisions. RaF states that emotion directly impact persuasion outcomes and constantly interacts with cognitive assessment. When there is a divergence between emotion and cognition, people tend to rely on emotions to make decisions (Loewenstein, Weber, Hsee, & Welch, 2001).

Based on these theories and previous studies discussed above, the following process model is proposed (See Figure 7). Parents have preexisting thoughts on HPV and HPV vaccine, which can predict their preexisting vaccine unacceptability. As reported by previous studies, common cognitive factors that can predict vaccine-related attitudes include knowledge, safety concern, perceived severity, perceived susceptibility, and efficacy (Brewer & Fazekas, 2007). Thus, the present study also measures these factors. Preexisting HPV vaccine unacceptability will have a direct impact on parents' vaccine unacceptability after the intervention. Some individual differences, such as gender, political views, and whether parents have girls, can influence their preexisting thoughts.

Messages can also lead to judgement changes. When parents are exposed to one of the messages, the decision-making process follows two routes. The first route involves cognitive

processing. The message will influence parents' post-test cognitive evaluations, which in the end impact their post-test vaccine unacceptability. These cognitive factors include posttest knowledge, safety concern, perceived severity, perceived susceptibility, and efficacy. In the second route, the message evokes different emotions that impact vaccine unacceptability. At the same time, emotions directly influence all cognitive factors as mentioned above.

Chapter 9 Methods

9.1 Participants and Procedure

Using Mechanical Turk and Qualtrics, the study recruited 301 parents who have not vaccinated their children. The criteria for enrollment were: (a) were responsible for children's health care, (b) had least one child between 11-18 living with them, and (c) had never had their child (children) vaccinated for HPV. Data collection was limited to the U.S.

The parents first completed a series of pretest questions measuring their demographics, prior HPV vaccine related knowledge, perceived susceptibility, severity, barriers, efficacy, and vaccine unacceptability. Details about the measures are discussed in section 9.4.

Then respondents were randomly assigned to read one of four pro-vaccine messages. After reading the message, participants completed questions measuring their emotional responses, current perceived susceptibility, severity, barriers, efficacy, and vaccine unacceptability.

9.2 Sample Size and Power Analysis

A power analysis was conducted with G*Power 3 (Faul, Erdfelder, Lang, & Buchner,

2007). The summary effect size (d) of .33 (95% CI .28-.38, k =190, N=37,449) was obtained from Sheeran, Harris, and Epton's meta-analysis on experiments studies examining risk messages and intention changes (2014). 75 participants were needed in each condition based on a two-sided type I error of .05 and a type II error.2 (80% power). Thus, the total sample size needed was 300 (75 × 4).

9.3 Messages

The present study used a 2 (pro- vs. anti- organization)× 2 (high vs. low expressed emotion) between-subjects design. Copies of the messages are in Appendix 1. All four messages began with describing the risks of HPV followed by a source commenting on the vaccine. Then, side effects of HPV vaccine were discussed. The messages end by asking parents to talk to doctors about the HPV vaccine.

These messages were different in the source and number of emotion words. Message 1 and 3 which were pro-organization mentioned that the CDC was supporting this message and the CDC could be trusted. Message 2 and 4 which were anti-organization stated that National Health College of Pediatrics (NHCP) was attacking this message and NHCP could not be trusted. NHCP was a made-up anti-vaccine organization that did not exist.

Messages in the high expressed emotion condition contained more and stronger emotion words (message 1 and 2). They intended to arouse fear towards HPV by stressing that HPV could lead to cancer and death. These messages might also evoke guilt by asking parents to imagine that unvaccinated children get cancer later. At the same time, these messages aimed to arouse the feelings of confidence and trust towards HPV vaccine by emphasizing that the vaccine was safe with minimal reactions. These messages also said that viewers should trust/reject the suggestions from the source. In contrast, messages in the low expressed emotion condition did

not contain any emotion words (message 3 and 4). These messages avoided inducing strong emotional responses from viewers. For example, instead of saying patients "suffer from" a cancer, these messages use "diagnosed" to prevent intense feelings. These messages also stated that viewers should accept/question the suggestions from the source.

9.4 Measures

Confirmatory factor analysis was conducted using AMOS. Results supported a six-factor measurement model for pretest measures, CMIN/DF = 2.58, CFI = .95, RMSEA = .07. These six factors were named as vaccine unacceptability, perceived knowledge, safety concern, perceived severity, perceived susceptibility and efficacy. Details regarding these factors are discussed as below.

Vaccine Unacceptability. Participants indicated how much they agreed with the statement that it was better for their children to get the disease and get protected from it naturally than to be vaccinated on a 7-point scale ranging from strongly disagree to strongly agree.

Perceived Knowledge. Participants indicated how much they thought they knew the topic of HPV, understood the risks of HPV and the issue of HPV vaccine (α=.91). For this measure and all the measures discussed as below, participants indicated how much they agree with each of the statement on a 7-point scale ranging from strongly disagree to strongly agree. The αs represented measures in the pre-test. Details regarding questions and items appear in Appendix 2.

Safety Concern. Participants indicated their concerns about the side effects, safety and possible negative consequences of HPV vaccines (α=.89). The three items were adapted from Madhivanan's study (2014).

Perceived Severity. Perceived severity of HPV was measured with 3 items (α=.87). Participants were asked to rate how much they believed that HPV could be harmful and cause health problems, and HPV caused disease could be harmful. Items were adapted from Witte's study (1992).

Perceived Susceptibility. Perceived susceptibility of HPV was measured with 3 items (α=.77). Items were adapted from Witte's study (1992). Participants indicated how much they agreed that their child were at risk, might get HPV, or get HPV caused cancer in the future.

Efficacy. Behavioral efficacy of the vaccine in preventing disease was measured using three items adapted from Madhivanan's study (2014) (α=.82). Participants indicated how confident that HPV vaccines could have a positive effect on their children's health, prevent diseases and HPV caused cancer.

Discrete Emotions. Emotions towards the message were operationalized by the Communication via Analytic and Syncretic Cognition Scale (CASC), which could assess both biological and higher-level social, cognitive, and moral emotions (Buck, Anderson, Chaudhuri, & Ray, 2004). The scale was adapted to assess emotions particularly relevant to vaccination. Participants self-reported their levels of 20 discrete emotions after reading the message, which included fear, anger, sympathy, sadness, scorn, confidence, guilt, irritation, worry, safety, scare, pity, indignation, compassion, contempt, remorse, disrespect, regret, sorry, and protect.

Demographic factors. Parents indicated their age, sex, education, race, the number of boys and girls they had, and political views. Political views were measured on a 7-point scale ranging from extremely liberal (left) to extremely conservative (right).

Descriptive statistics, including the means and standard deviations of all variables and their zero-order correlations, are reported in Table 3.

Chapter 10 Results

10.1 Participants

Among 301 valid samples, 82.7% (N=249) were females. Most participants were white (N=245). In addition, 43.2% (N=130) were between 35 to 44 years old. Most people did not have a bachelor degree in college (57.8%, N=174), 29.2% had a bachelor degree (N=88), and 13% had a master, doctoral, or professional degree (N=39). In terms of participants' educational background, the sample population in the present study could represent the general population. As reported by the U.S. Census Bureau in 2015, about one in three adults had a bachelor's degree and 12% had an advanced degree (Ryan & Bauman, 2016). Overall, participants' political opinion was slightly liberal (M=3.81, SD=1.91).

10.2 Baseline

An almost equal number of participants was randomly assigned to each of the four groups (Pro-organization and high emotion condition: 73; Anti-organization and high emotion condition: 77; Pro-organization and low emotion condition 3: 72; Anti-organization and low emotion condition 4: 79). One-way ANOVA indicated that there were no differences in preexisting knowledge, concern, perceived severity, perceived susceptibility, efficacy, and vaccine unacceptability before participants were exposed to the message. Thus, we may conclude that participants' vaccine-related thoughts were at the same level before the intervention.

10.3 Manipulation Check

Emotion Induction Check. In order to figure out if messages that express high levels of emotions could induce stronger emotional responses among viewers than messages that are less emotional, independent sample T-test was used to explore participants' self-reported emotional responses after the intervention. Results indicated that participants who were exposed to high expressed emotion messages reported a higher level of anger (M=3.73, SD=1.98) and irritation (M=4.16, SD=2.02) than participants who read low expressed emotion messages (anger: M=3.21, SD=1.73, t(297)=2.41, p=.02, Cohen's d=.28; irritation: M=3.39, SD=1.84, t(298)=3.45, p<.001, Cohen's d=.40). Thus, we may conclude that the emotion induction was successful. Since anger and irritation were similar emotions, they were averaged into a new variable "anger".

There was no manipulation check for pro- vs anti- organization messages.

Message Effectiveness Check. Paired sample T-test was used to examine if the designed messages could successfully change participants' cognitive responses from pre- to post-test (See Table 4). In order to control for multiple comparisons, FDR (false discovery rate) method was used to adjust each of the p value (Benjamini & Hochberg, 1995). Results show that pro-organization and high emotion condition reduced participants' safety concern and perceived efficacy. Pro-organization and low emotion condition increased perceived knowledge while reduced safety concern and vaccine unacceptability. Anti-organization and low emotion condition decreased safety concern and perceived efficacy while increased perceived susceptibility. Therefore, it can be concluded that except for the anti-organization and high emotion condition, other three messages designed for the present study were effective in changing participants' cognitive assessments.

10.4 Hypotheses Testing

Hypothesis 1 predicted that mothers and fathers were different in their preexisting HPV vaccine related cognitive assessments. Independent-samples T-test result indicated that mothers reported higher levels of perceived HPV knowledge at baseline, $t(299)=-3.81$, $p<.001$, $M=5.84$ vs. 5.12, $SD=1.21$ vs. 1.32, Cohen's $d=.56$. Mothers had more safety concerns at baseline, $t(299)=-2.36$, $p=.02$, $M=5.91$ vs. 5.40, $SD=1.40$ vs. 1.47, Cohen's $d=.35$. Moreover, mothers perceived higher levels of susceptibility than fathers, $t(298)=-1.94$, $p=.05$, $M=3.61$ vs. 3.21, $SD=1.34$ vs. 1.30, Cohen's $d=.30$. These findings supported Hypothesis 1a, 1b, and 1d. Fathers reported higher levels of efficacy at baseline, which did not support Hypothesis 1e, $t(299)=2.13$, $p=.03$, $M=4.77$ vs. 4.28, $SD=1.32$ vs. 1.54, Cohen's $d=.33$. Gender differences did not exist in perceived severity and unacceptability at baseline. These findings did not support Hypothesis 1c and 1f.

Hypothesis 2 and 3 stated that parents who had at least one girl would report different levels of HPV vaccine related cognitive thoughts compared to parents who only had boys. However, results did not find any significant differences. Hypothesis 2 and 3 were therefore rejected.

Hypothesis 4 and 5 predicted that differences in political views would result in different preexisting thoughts regarding HPV vaccine. Correlation analysis results supported Hypothesis 4a ($r=.26$, $p<.001$), which stated that more conservative people would report higher levels of preexisting safety concerns. Moreover, people who were more liberal reported higher levels of preexisting perceived susceptibility of HPV ($r=-.21$, $p<.001$) and efficacy ($r=-.21$, $p<.001$), which supported Hypothesis 5c and 5d. Hypothesis 4b, 5a and 5b were rejected.

Hypothesis 6 and 7 predicted that messages that expressed stronger emotions and attacked an organization could decrease parents' vaccine unacceptability. After controlling for baseline unacceptability, Two-way ANOVA indicated a significant interaction effect on vaccine unacceptability, F (1, 296) =7.22, p=.008, partial eta^2=.02. Pro-organization and high emotion condition led to the highest level of vaccine unacceptability (M=3.49, SD=1.76). Anti-organization and low emotion condition had the second highest level of vaccine unacceptability (M=3.29, SD=1.76) followed by anti-organization and high emotion condition (M=3.05, SD=1.61). Pro-organization and low emotion condition led to the least level of vaccine unacceptability (M=2.94, SD=1.57). Results did not reveal significant main effects, Pro-/anti-organization: F(1, 296)=.69, p=.41, partial eta^2=.002; Emotion: F(1, 296)=.09, p=.77, partial eta^2<.001.Therefore, H6 and H7 were rejected.

10.5 Additional Testing

In order to find out why pro-organization and low emotion condition led to the least level of vaccine unacceptability, a two-way ANOVA was done to explore the messages effects on anger. A significant interaction effect was discovered, F (1, 296) =7.41, p=.007, partial eta^2=.02. Pro-organization and high emotion condition aroused the highest level of anger (M=3.96, SD=1.86) followed by anti-organization and high emotion condition (M=3.94, SD=1.78) and anti-organization and low emotion condition (M=3.80, SD=1.51). Pro-organization and low emotion condition evoked the least level of anger (M=2.75, SD=1.65).

10.6 Model Testing

According to the correlation analysis, whether parents had girls was not significantly correlated with any of the variables. Thus, it was excluded from the proposed model. The revised proposed model appears in Figure 8. Path analysis results show that several paths generated by

the procedure were not statistically significant ($\chi 2$=480.12, df=101, p<.001, CMIN/DF=4.75, CFI=.83, TLI=.71, NFI=.80, RMSEA=.11, SRMR=.15). Insignificant paths included female sex to pretest severity (p=.45) and susceptibility (p=.07), conservatives to pretest knowledge (p=.41), severity (p=.14), and unacceptability (p=.95), emotion level to posttest knowledge (p=.91), concerns (p=.69), susceptibility (p=.70), severity (p=.62), and efficacy (p=.10), as well as pro-/anti- organization to posttest knowledge (p=.46), concerns (p=.17), susceptibility (p=.34), severity (p=.97), and efficacy (p=.15). Pretest knowledge (p=.21), concerns (p=.18) and susceptibility (p=.66) to pretest vaccine unacceptability, anger to posttest knowledge (p=.94), concerns (p=.13), and susceptibility (p=.25), as well as posttest knowledge (p=.26), efficacy (p=.20), and anger (p=.23) to unacceptability were also insignificant. After eliminating these paths, the revised model shows a better but not good fit $\chi 2$ = 510.45, df=130, p=.00, CMIN/DF= 3.93, CFI= .83, TLI=.77, NFI=.79, RMSEA= .10, SRMR=.12.

According to correlation results, there were several possible significant paths that had not included in the previous two models due to significant correlations. These possible significant paths included conservatives (r=.14), pretest knowledge (r=.20), concerns (r=.33), susceptibility (r=-.16), efficacy (r=-.42), and unacceptability (r=.21) to anger, female sex to posttest knowledge (r=.17) and efficacy (r=-.14). Other possible paths included pretest knowledge to posttest concerns (r=.30) and efficacy (r=-.27), pretest concerns to posttest knowledge (r=.22), susceptibility (r=-.22), and efficacy (r=-.60), pretest severity to posttest knowledge (r=.26), susceptibility (r=.13), and efficacy (r=.12), pretest susceptibility to posttest concerns (r=-.19), severity (r=.18), and efficacy (r=.40), as well as pretest efficacy to posttest concerns (r=-.56), severity (r=-.32), and susceptibility (r=.37). These paths were put into the revised model with insignificant paths removed. The final model (see Figure 9) shows a good fit, $\chi 2$ = 196.56,

df=119, p=.00, CMIN/DF= 1.65, CFI= .97, TLI=.95, NFI=.92, RMSEA= .05, SRMR=.06. According to the model, before being exposed to the message, females reported lower levels of vaccine efficacy (β =-.16). Females reported higher levels of safety concerns (β =.18) and knowledge (β =.23). Those who reported being more conservative reported lower levels of efficacy (β =.19) and perceived susceptibility (β =.20). However, those who reported being more conservative reported higher levels of concerns (β =.28).

Before reading the message, participants' perceived vaccine efficacy (β =-.34) and perceived susceptibility (β =-.13) negatively predicted pretest vaccine unacceptability.

Messages that were more emotional (β =.18) and anti-organization (β =-.13) were more likely to evoke stronger anger. However, messages that were both emotional and pro-organization also invoked anger (the interaction term in the model). At the same time, the strongest predictor of anger was baseline levels of perceived vaccine efficacy. People who perceived low levels of vaccine efficacy at baseline were more likely to feel angry after reading the message (β =-.40).

As is to be expected, participants' baseline levels of perceived susceptibility (β =.82), severity (β =.67), concerns (β =.79), knowledge (β =.65), and efficacy (β =.73) significantly predicted posttest levels of the same variables. Pretest vaccine safety concerns negatively predicted posttest perceived HPV vaccine efficacy (β =-.16). Preexisting efficacy negatively predicted posttest safety concerns (β =-.10). Anger negatively predicted posttest severity (β =-.12) and efficacy (β =-.09). Conservatives reported slightly lower levels of posttest perceived susceptibility (β =-.10).

Controlling for baseline vaccine unacceptability (β =.64), greater posttest vaccine concerns led to greater posttest vaccine unacceptability (β =.11). Higher perceived severity of HPV led to lower posttest vaccine unacceptability (β =.14).

Chapter 11 Discussion

11.1 When Anger Backfires

The present study showed that about half of parents had no opinion about HPV vaccines or even believed that their children could be protected by natural infection. It indicates that there is a need to increase awareness of HPV vaccines among parents who have not vaccinated their children. However, path analysis indicated that the overall effect of designed messages did not help reduce vaccine unacceptability. Instead, messages had a small effect of *increasing* unacceptability. Moreover, even though increasing the perceived severity of HPV improved vaccine acceptability, the anger evoked by messages *reduced* perceived severity. Since each one of the four messages had different effects on parents' cognitive and emotive responses, each message should be examined separately.

Results revealed that among the four messages, the one supporting the organization and expressing fewer emotions slightly increased vaccine acceptability. In contrast, the message using more emotional language and supporting the organization backfired. One possibility was that the over-the-top emotional tone in this message led people to think that they were being manipulated in the experiment. The reason why pro-organization and low emotion condition was effective in decreasing vaccine unacceptability might be due to the fact that it did not arouse much anger among parents.

According to previous studies, anger is elicited when people face obstacles or offenses. It is associated with a great attention to attack or revenge the anger source (Lazarus, 1991). Anger encourages information seeking in order to reduce uncertainty and can lead to attitude change. For example, one study revealed that anger aroused by juvenile crime and domestic terrorism predicted the support of related proposed policies to address these issues (Nabi, 2002). However, studies also find that anger can backfire and reduce the effectiveness of persuasion (e.g. van Dijk, van Kleef, Steinel & van Beest, 2008; Wubben, Cremer & Dijk, 2009).

The backfire effect of anger may be explained by psychological reactance theory (PRT). PRT states that people can aversively react to a message or situation (Brehm, 1972). It has been recently used to understand the failure of many health messages. Some studies indicate that anger is central to the psychological reactance. Messages that arouse high levels of anger may result in the aversive state among the audience (Cho & Sands, 2011; Quick & Stephenson, 2008; Rains & Turner, 2007). Controlling, forceful, and strong language as well as loss-framed appeals are more likely to lead to psychological reactance, and messages that are not forceful and hide the source's intentions may be less likely to cause reactance (Miller, Lane, Deatrick & Young, et al., 2007; Miller, Ivanov, Sims & Compton, et al., 2013; Kronrod, Grinstein, & Wathieu, 2012). In the present study, the language used in the non-emotional and pro-organization message is polite and less controlling. Thus, viewers may not feel angry and are more willing to change their preexisting attitude. This finding is useful for message design. Messages are recommended to avoid arousing anger among viewers by including less emotionally intensive language. Another possibility is to evoke positive and prosocial emotions rather than anger-inducing emotions. For example, messages can state that vaccination can lead to feeling of safety and build trust in communities.

11.2 When Messages Attack Anti-Vaccine Groups

Recent studies have tried to combat vaccine-related misinformation by correcting myths and presenting claims from both sides. However, these methods can backfire and harm vaccine intentions (Dixon & Clarke, 2013; Nyhan & Reifler, 2015). The present study aimed to increase vaccine acceptability by attacking and discrediting a fake anti-vaccine group. Nevertheless, results implied that attacking anti-vaccine groups might not be effective in influencing vaccine intentions. However, more studies with different messages are needed to further test the strategy of attacking an anti-vaccine organization.

11.3 Political Factors

The present study revealed two paths that political views could influence vaccine-related cognitive responses and eventually affected vaccine unacceptability. In the first path, more conservative individuals had higher levels of preexisting concerns about vaccine safety. These preexisting concerns resulted in higher concerns after the intervention, which in the end increased vaccine unacceptability. In the second path, more liberal individuals had higher preexisting levels of perceived vaccine efficacy, which related to their greater acceptance of vaccines at baseline and, in turn, after the messages. These results indicate that political views can influence people's beliefs about the HPV vaccine, which is consistent with previous studies suggesting that government official's comments and political predispositions can impact vaccine-related attitudes (Gollust, Attanasio, Dempsey & Benson, et al., 2013). Public figures' negative comments about vaccine can decrease people's motivations to vaccinate (Zucker, Reiter, Mayer & Brewer, 2015). According to Kelman's model of opinion change (1958), individuals may adopt certain attitudes and behaviors because they identify with a leader and accept his/her ideas. Thus, it is possible that President Trump's negative comments about

vaccine safety affect conservative individuals' vaccine acceptability. Another reason may be that conservative individuals believe that HPV vaccine can increase young people's sexual activities and lead to promiscuity (Casper & Carpenter, 2008) even though studies have found no relationship between getting HPV vaccine and sexual activity-related outcomes (Bednarczyk, Davis, Ault, Orenstein, et al., 2012). Future studies can design and test messages that target related misperceptions.

11.4 Parents' and Children's Gender

The present study revealed two paths that gender differences could influence vaccine-related cognitive responses and eventually affect vaccine unacceptability. In the first path, mothers had higher levels of preexisting concerns about vaccine safety. These preexisting concerns resulted in higher concerns after the intervention, which in the end increased vaccine unacceptability. In the second path, fathers had higher levels of preexisting perceived vaccine efficacy. Preexisting vaccine efficacy negatively predicted preexisting vaccine unacceptability, which in the end predicted vaccine unacceptability. These findings indicate that mothers and fathers may be different in vaccine-related attitudes. Thus, whether existing campaigns are equally effective in persuading different genders remain a question. However, most vaccine messages mainly target females. Although one prior study (Gainforth, Cao & Latimer-Cheung, 2012) implied that mothers and fathers may approach HPV and HPV vaccines differently based on the sex of their children, the present study and a few previous studies (Olshen, Woods, Austin, Luskin, et al., 2005; Slomovitz, Sun, Frumovitz, Soliman, et al., 2006; Zimet, Mays, Winston, Kee, et al., 2000), indicate that children's sex does not impact parents' decisions. Thus, future studies could explore if mothers and fathers differ in vaccine-related decision-making, and potentially design interventions based on the gender of parents.

11.5 Limitations and Conclusion

Several limitations should be noticed before interpreting the results. First, like all the other experiments, participants in this study were forced to be exposed to a message. Whether the results can represent how people process these messages in the natural settings remains unknown. Second, attitude changes do not necessarily predict behavior changes (Webb & Sheeran, 2006). Whether a message similar to the one here that was less emotional and did not mention the opposition can motivate parents to actually vaccinate their children remains to be examined in the future. Third, the outcome measure was relatively weak. Future research should include multiple items to measure vaccine unacceptability. Fourth, several moderators regarding individual differences should be controlled or analyzed in future studies. For example, whether parents in this study had vaccinated or not remained unknown. Their vaccination experience might result in different perceptions of HPV and HPV vaccines. Another potential moderator could be whether participants are more emotional or rational. It is possible that individuals who are more emotional can experience a higher level of anger which may result in more reactance. Fifth, the current study did not have a manipulation check to make sure that participants noticed the source. Finally, over-the-top emotional words used in high emotion messages could evoke anger or make participants believe that they were manipulated, which might affect the results. Future studies should be more cautious about the message design.

In conclusion, the present study explores the effects of four newly-designed messages on HPV vaccine unacceptability. It shows that only the message with less emotional and controlling languages and features a credible organization's support can reduce vaccine unacceptability. It also reveals that messages that arouse high levels of anger may lead to psychological reactance. Political views and gender differences exist in HPV vaccine-related cognitive assessments. These

findings can be useful to practitioners. At the same time, more studies are needed in order to design a powerful message without causing reactance and meet different needs of various demographics.

Chapter 12 Conclusion

This dissertation contained two studies with different methods to examine existing vaccine information and test original vaccine messages. Study 1 used computational methods to explore topic evolution and popularity in vaccine-related online messages. Results revealed that pro-vaccine messages that contained personal stories were more popular than scientific knowledge. Anti-vaccine messages that discussed flu shots and government conspiracy were the most popular. Since 2016, even though more pro-vaccine messages appeared online, anti-vaccine messages were more popular and the comparative popularity of anti-vaccine messages increased fast. Newly-emerged anti-vaccine topics (e.g. CDC conspiracy) should be noted. Study 1 also indicated that messages that contained high levels of emotional contents and undermine the credibility of an organization could be persuasive. Based on these findings, study 2 designed four messages and tested if these messages could decrease HPV vaccine unacceptability among parents who had not vaccinated their children. Results revealed that only the pro-organization message with low levels of emotions could reduce vaccine unacceptability. Political views and gender of parents could influence vaccine-related cognitive responses and eventually affected vaccine unacceptability. These findings can help researchers design effective interventions as well as develop programs to track and combat health misinformation.

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Tables and Figures

Figure 1. Pro-Vaccine Wordcloud

Figure 2. Anti-Vaccine Wordcloud

Table 1. Topics of Pro-Vaccine Messages

Name Assigned to Topic	Top Terms in Topic	$N_{article}$	N_{sum}	$N_{average}$
Flu Shot	Flu, Shot, Season, Influenza	82	110464	1347
Vaccines For Children	Child, Protect, Baby, Cough	62	293579	4735
HPV Vaccine	HPV, Cancer, Women, Cervix	57	40330	708
Side Effects	Infect, Disease, Virus, Side	56	12926	231
Disease Outbreak	Measles, Outbreak, Rate, Unvaccinated	45	114631	2547
Benefit	Benefit, Reduce, Death, Cost	39	13244	340
Anti-Vaccine Movement	Autism, Link, Antivaccine, Movement	38	79324	2087
Personal Story	Kid, Die, Year, Fact	37	1240291	33521
Guidelines	Recommend, Program, Care, State	29	3358	116
Studies	Study, Found, Research, Patient	25	39469	1579
Adverse Case	Safety, Adverse, Case, Event	23	108623	4723
Ingredients	Contain, Cell, Thimerosal, Aluminum	22	17358	789
Parents' Hesitancy	Parent, Mother, Refuse, Concern	16	10183	636

Development	CDC, FDA, Clinic, Manufacture	10	2517	252

Note: $N_{article}$ represents by the number of articles belonging to the topic. N_{sum} stands for the total number of the shares, reactions, and comments across all articles within a topic. $N_{average}= N_{sum}/ N_{article}$

Table 2. Topics of Anti-Vaccine Messages

Name Assigned to Topic	Top Terms in Topic	$N_{article}$	N_{sum}	$N_{average}$
Child Deaths	Children, Infant, Death, Adverse	109	857570	7868
Doctors' Testimonials	Doctor, Research, Fact, Manipulation	62	243350	3925
CDC Conspiracy	CDC, Thompson, Pharmaceutical, Industry	42	100261	2387
Vaccine Injury Compensation	Government, Injury, Federal, Compensation	36	124475	3458
Flu Shot	Flu, Season, Shot, Risk	25	421982	16879
Personal Story	Month, Day, Son, Daughter	25	219767	8791
Vaccine Damage	Damage, Toxic, Inject, Virus	22	21454	975
Autism	Autism, MMR, Wakefield, Link	20	120897	6045

Government Conspiracy	Government, Chip, Organ, Military	18	203154	11286
HPV Vaccine	HPV, Gardasil, Women, Cervix	14	37965	2712
Anti-Vaccine Study	Lancet, Monkey, Tumor, Pediatric	5	5925	1185
Polio Vaccine	Polio, Salk, Virus, Paralysis	4	1358	340

Figure 3. Frequency over time of Pro- and Anti-Vaccine Messages from Top Google Search Results

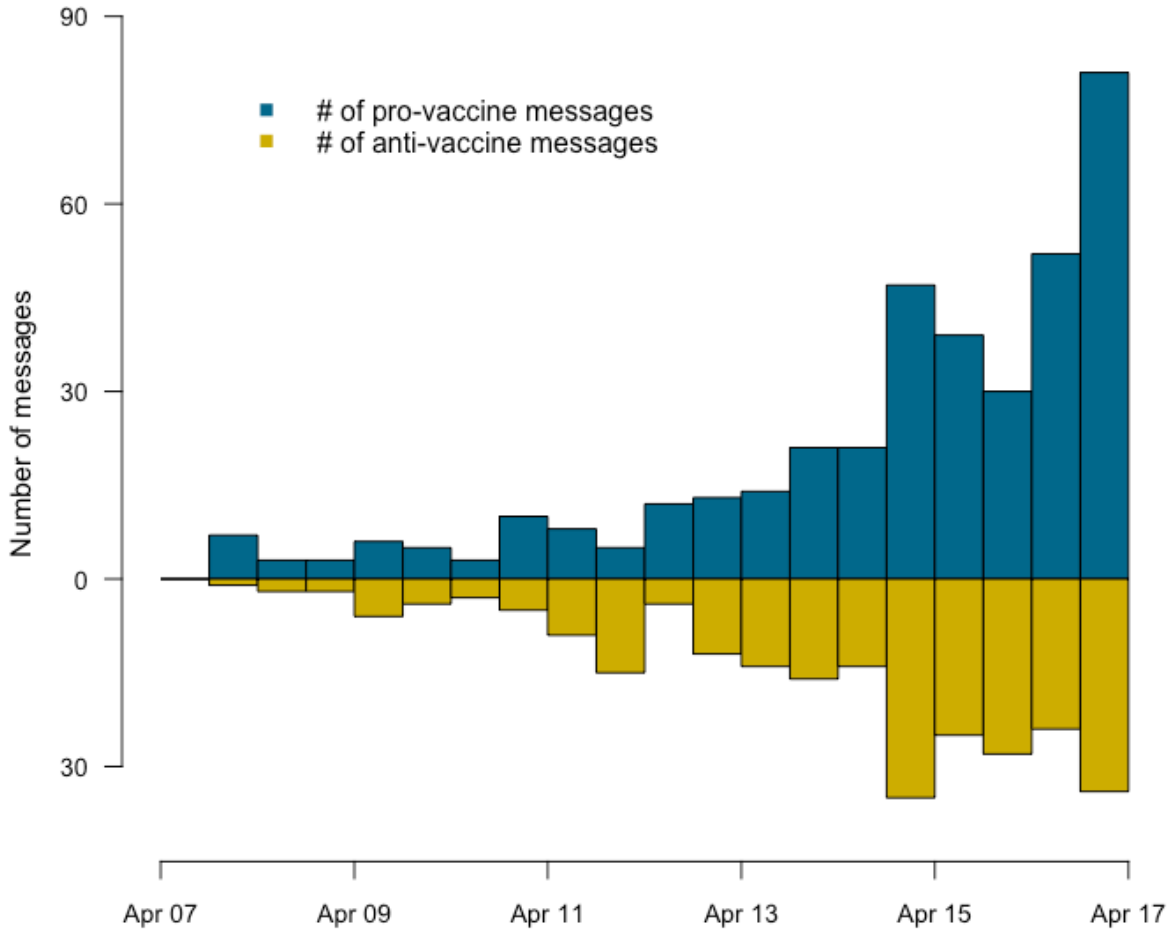


Figure 4. Changes in the Online Popularity of Pro- and Anti-Vaccine Messages

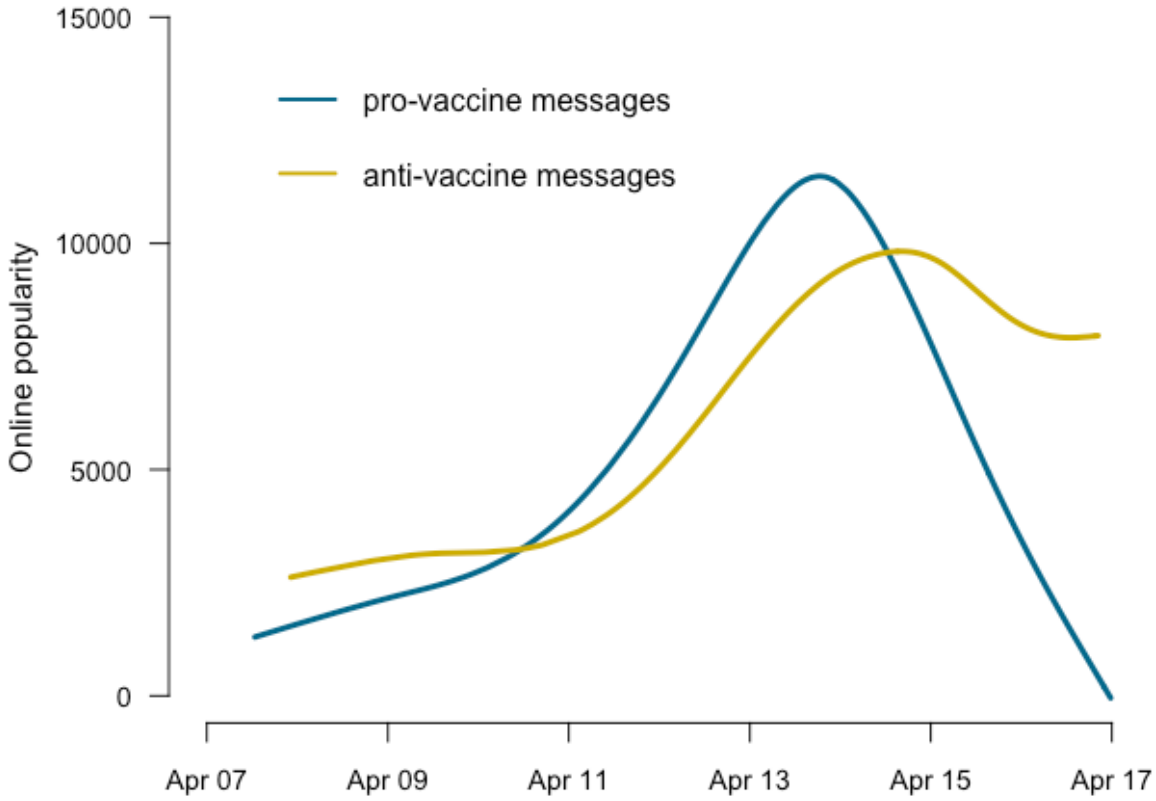
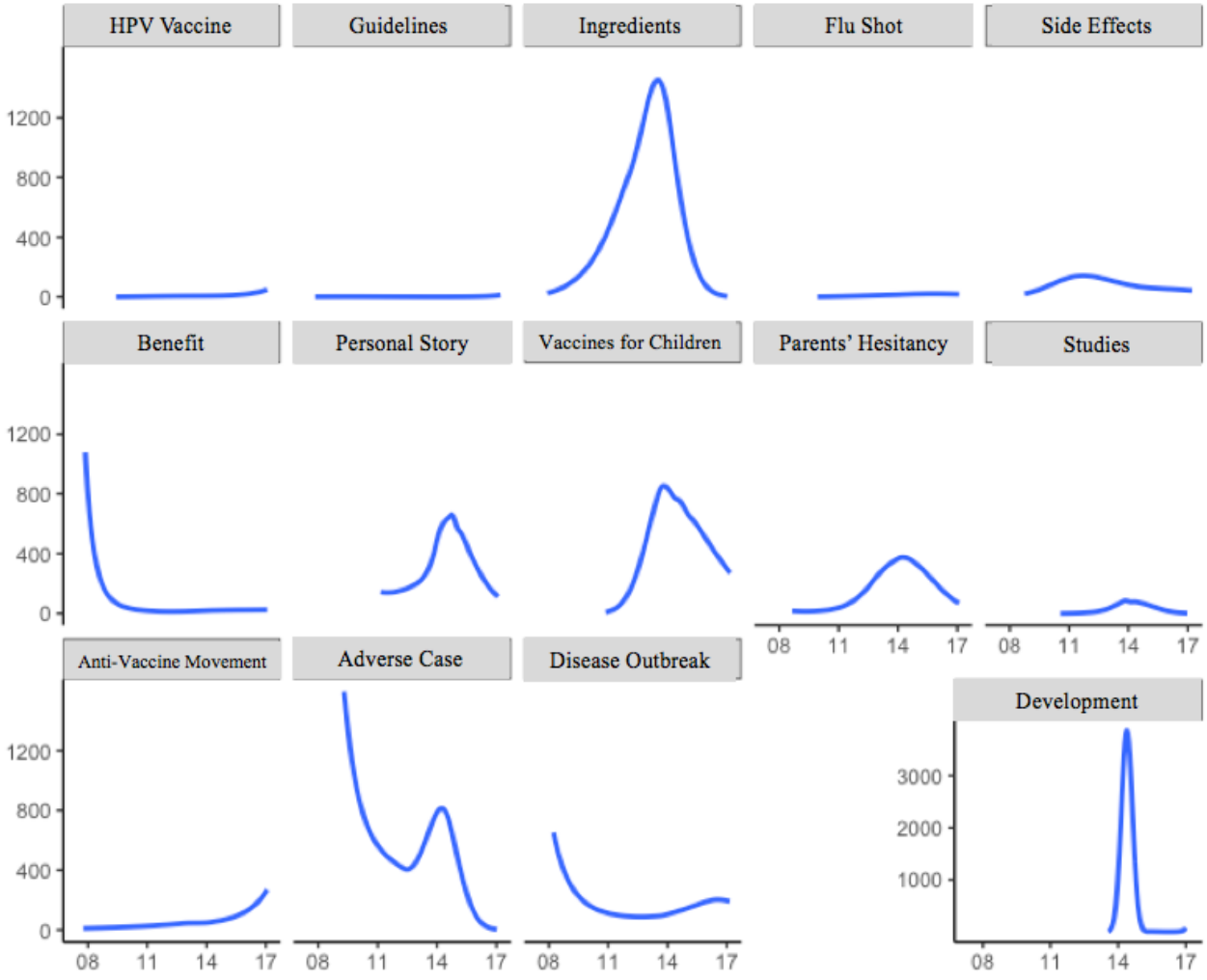


Figure 5. Trends in Pro- Vaccine Topics and Their Online Popularity



Note: Time was plotted on the x-axis. The topic's popularity was plotted on the y-axis.

Figure 6. Trends in Anti- Vaccine Topics and Their Online Popularity

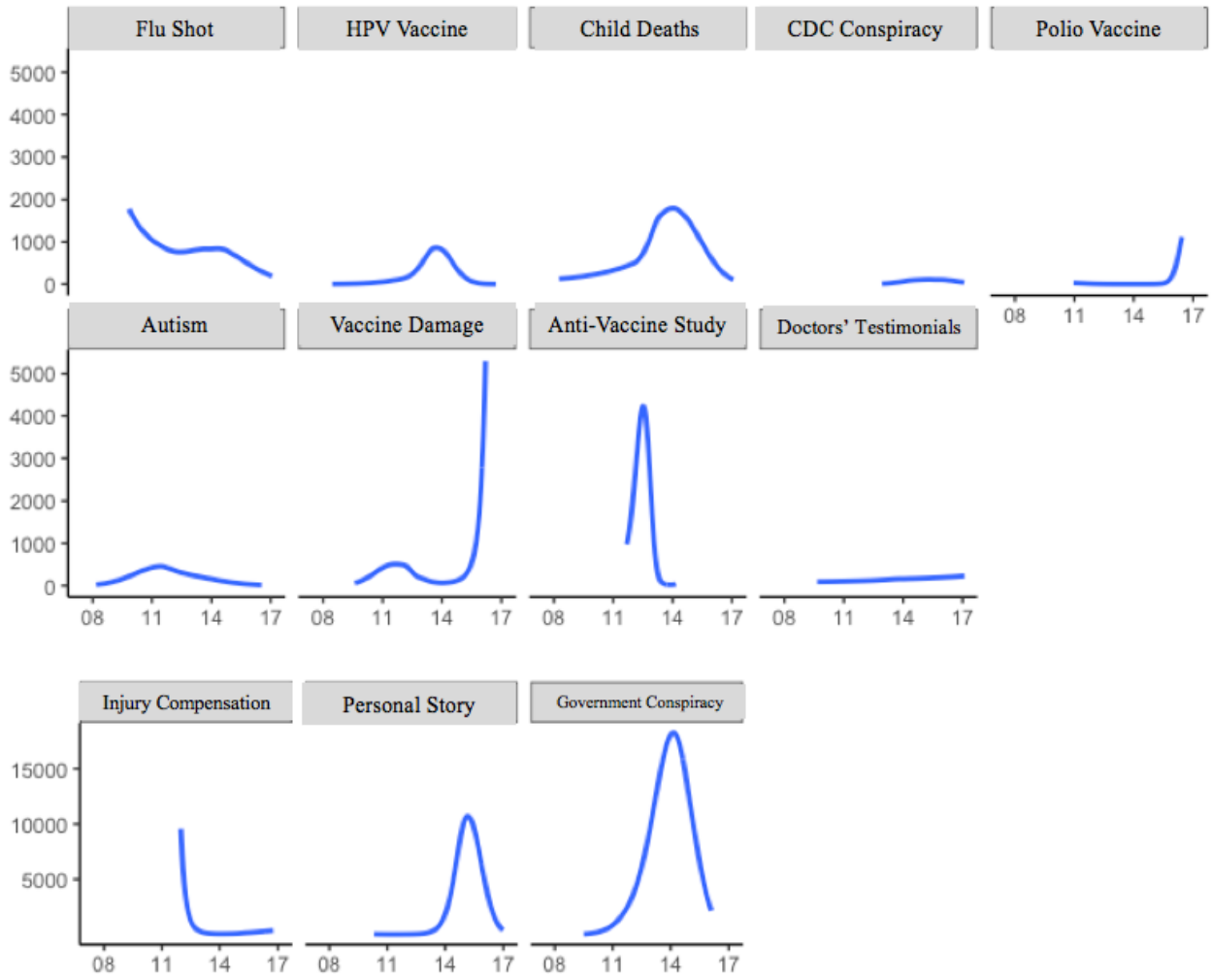


Table 3. Descriptive Statistics for All Variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1.00																		
2	.693**	1.00																	
3	-0.09	-0.05	1.00																
4	0.10	.118*	-0.08	1.00															
5	-0.03	0.00	0.10	-0.02	1.00														
6	0.07	0.01	0.05	0.08	0.02	1.00													
7	0.05	0.04	-0.09	.135*	-0.05	0.01	1.00												
8	0.01	.115*	.128*	0.00	0.05	0.00	-0.04	1.00											
9	.210**	.236**	0.05	.139*	0.09	-.147*	.184**	.145*	1.00										
10	-0.02	0.04	.215**	0.03	0.06	-0.01	0.05	0.11	.201**	1.00									
11	-.124*	-0.05	.174**	0.03	0.10	0.02	0.04	-0.01	.115*	.652**	1.00								
12	.222**	.221**	.135*	.256**	0.11	-0.04	0.07	0.09	.322**	.329**	.224**	1.00							
13	.228**	.256**	0.06	.227**	0.07	-0.08	0.08	0.07	.326**	.302**	.154**	.855**	1.00						
14	-.210**	-.218**	-0.04	-0.08	0.01	-0.02	-0.01	0.01	-0.05	.270**	.260**	0.04	0.06	1.00					
15	-.236**	-.295**	0.02	-.167**	-0.04	0.01	-0.01	-0.02	-.161**	0.07	.188**	-0.03	-0.02	.682**	1.00				
16	-.152**	-0.01	0.11	-.206**	0.03	-0.02	-0.01	0.03	-.158**	0.02	0.01	-.216**	-.190**	.155**	.177**	1.00			
17	-0.10	0.04	0.05	-.172**	-0.04	-0.04	-0.03	0.06	-.167**	-0.01	-0.07	-.217**	-.198**	.129*	.155**	.819**	1.00		
18	-.374**	-.365**	-.122*	-.205**	-0.07	0.05	-0.02	-0.06	-.417**	-.257**	-0.05	-.573**	-.562**	.220**	.321**	.384**	.365**	1.00	

19	-.278**	-.276**	-.143*	-.197**	-0.10	0.10	-0.05	-0.11	-.444**	-.274**	-.120*	-.603**	-.608**	.117*	.235**	.396**	.421**	.853**	1.00
M	3.27	3.20	1.83	3.81	0.75	-0.04	0.00	0.01	3.62	5.72	5.88	5.82	5.59	5.62	5.77	3.54	3.70	4.37	4.15
SD	1.65	1.69	0.38	1.91	0.43	1.00	1.00	1.00	1.76	1.25	1.15	1.43	1.57	1.18	1.16	1.34	1.42	1.51	1.74

Note: 1=Pretest vaccine unacceptability, 2=Posttest vaccine unacceptability, 3=Female, 4=Conservative, 5=Whether parents have girls, 6=Pro-/anti- Organization, 7=Emotion, 8=Emotion× Organization, 9=Anger, 10= Pretest knowledge, 11= Posttest knowledge, 12=Pretest safety concerns, 13=Posttest safety concerns, 14=Pretest severity, 15=Posttest severity, 16=Pretest susceptibility, 17=Posttest susceptibility, 18=Pretest efficacy, 19=Posttest efficacy, $*p < .05$. $**p < .01$.

Table 4. Message Effectiveness Check Results

Condition	Pro-Organization and High Emotion		Pro-Organization and Low Emotion			Anti-Organization and Low Emotion		
Variable	Safety concern	Perceived efficacy	Perceived knowledge	Safety concern	Vaccine unacceptability	Safety concern	Perceived efficacy	Perceived susceptibility
$M_{pretest}$	6.00	4.32	5.49	5.52	3.29	5.91	4.24	3.62
$SD_{pretest}$	1.27	1.50	1.50	1.52	1.60	1.43	1.61	1.44
$M_{posttest}$	5.70	4.04	5.87	5.20	2.94	5.70	3.89	3.90
$SD_{posttest}$	1.50	1.75	1.09	1.67	1.57	1.56	1.87	1.48
t	2.56	2.55	-2.68	3.43	2.48	2.76	3.55	-2.86
df	72	72	71	71	71	77	78	77
p	0.01	0.01	0.01	0.001	0.02	0.01	0.001	0.01
adjusted p	0.04	0.04	0.03	0.01	0.03	0.01	0.01	0.01
d	-1.36	-1.12	-0.93	-2.13	11.67	-1.62	-1.35	7.00

Figure 7. First Proposed Model

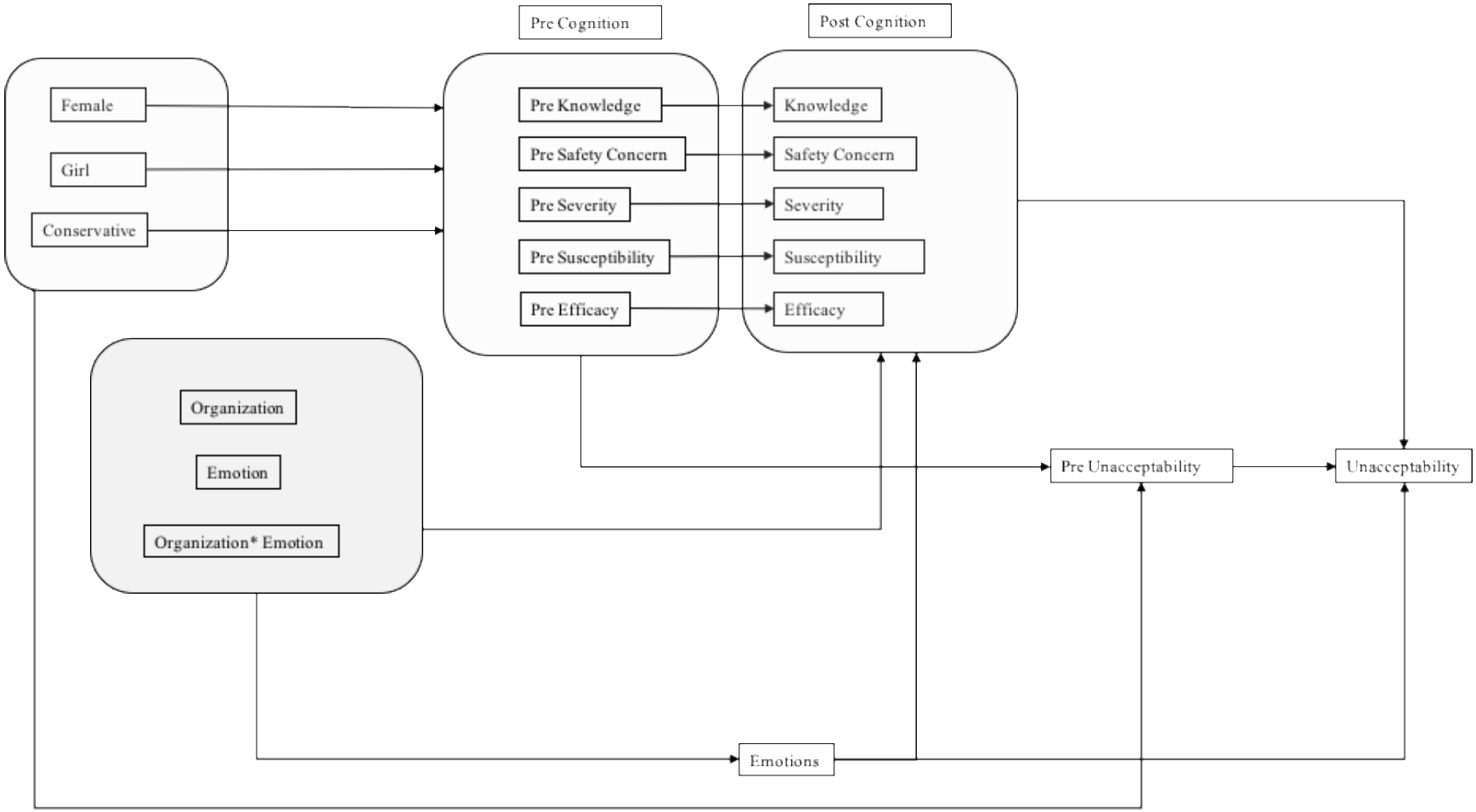


Figure 8. Revised Proposed Model

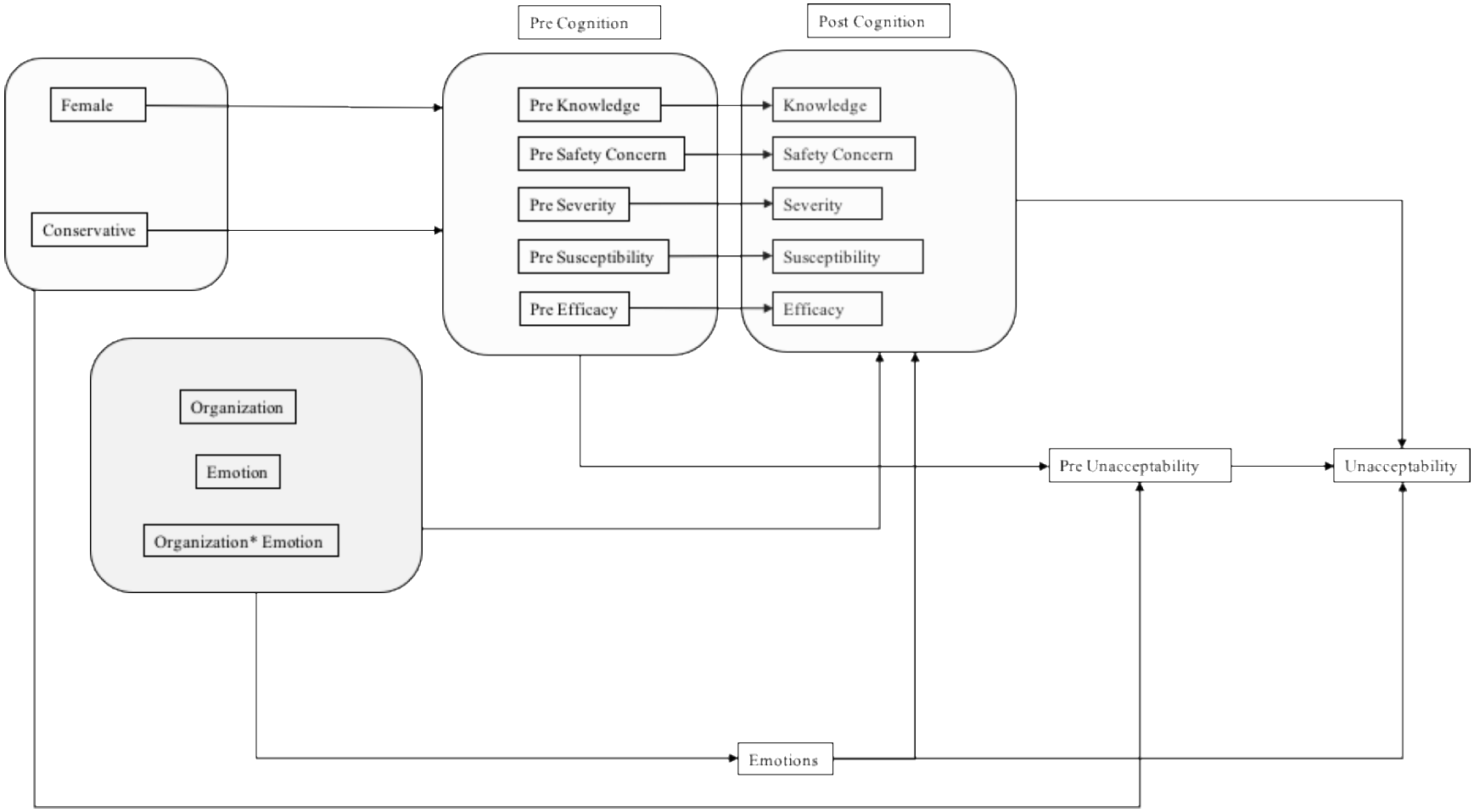
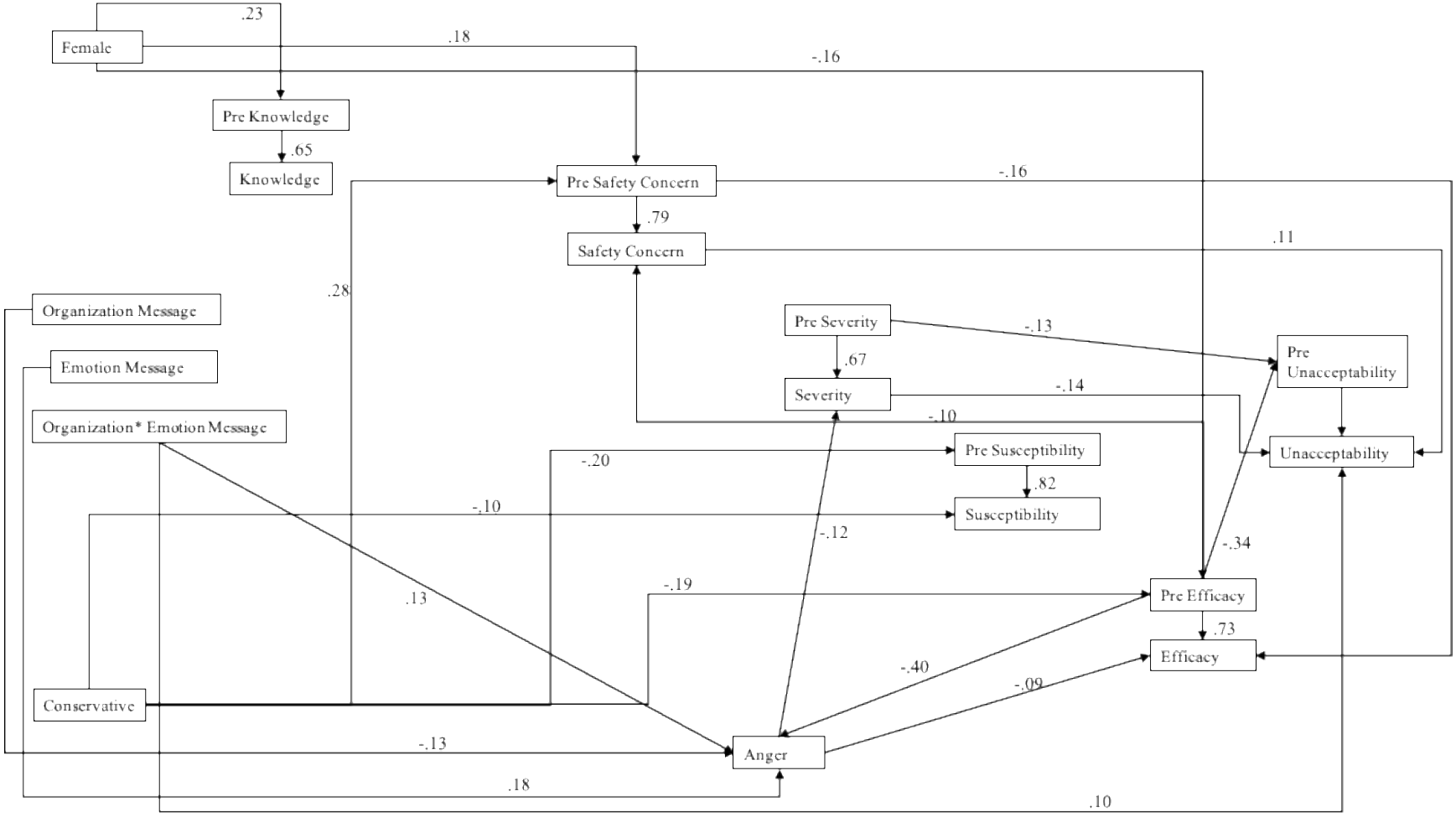


Figure 9. Final Model



Appendix 1 Messages

1. High Emotion and Pro-Organization

31,000 women and men **suffer badly** from a cancer caused by HPV every year in the United States. **More than 6,000 of them die.** HPV is transmitted sexually and about 80 million people in the U.S. are affected. HPV caused cancers include but not limited to cervical cancer, anal cancer and oropharyngeal cancer. **Centers for Disease Control and Prevention (CDC) has recommended that both girls and boys should receive HPV vaccine. People in CDC are highly competent, trustworthy and have no vested interest**. Their advice is **admired** by experts and scientists and they should be **trusted**. HPV vaccination can **save lives and prevent cancers!** HPV vaccine is **extremely safe.** People only experience **minimal reactions** similar to reactions from other vaccines or medicines, such as pain, redness, dizziness, fainting, nausea, and headache. HPV vaccination is typically not associated with any serious side effects. **You risk your children's lives if you do not get HPV vaccine for them** to protect them from this **extremely dangerous** cancer-causing virus. **Imagine that you do not vaccine your kids and they get cancer later. You will feel devastated.** Talk to your doctors about getting HPV vaccine for your kids.

2. High Emotion and Anti-Organization

31,000 women and men **suffer badly** from a cancer caused by HPV every year in the United States. **More than 6,000 of them die.** HPV is transmitted sexually and about 80 million people in the U.S. are affected. HPV caused cancers include but not limited to cervical cancer, anal cancer and oropharyngeal cancer. **However, National Health College of Pediatrics (NHCP) is attacking HPV vaccine by saying that neither boys nor girls should be vaccinated. People in NHCP are not competent, trustworthy and have vested interest**. Their advice is **dismissed** by experts and scientists and they should be **rejected**. HPV vaccination can **save lives and prevent cancers!** HPV vaccine is **extremely safe.** People only experience **minimal reactions** similar to reactions from other vaccines or medicines, such as pain, redness, dizziness, fainting, nausea, and headache. HPV vaccination is typically not associated with any serious side effects. **You risk your children's lives if you do not get HPV vaccine for them** to protect them from this **extremely dangerous** cancer-causing virus. **Imagine that you do not vaccine your kids and they get cancer later. You will feel devastated.** Talk to your doctors about getting HPV vaccine for your kids.

3. Low Emotion and Pro-Organization

31,000 women and men are **diagnosed** with a cancer caused by HPV infection every year in the United States. HPV is transmitted sexually and about 80 million people in the U.S. are affected. HPV caused cancers include but not limited to cervical cancer, anal cancer and oropharyngeal cancer. **Centers for Disease Control and Prevention (CDC) has recommended that both girls and boys should receive HPV vaccine. People in CDC are highly competent, trustworthy and have no vested interest**. Their advice is **accepted** by experts and scientists and they should be **heeded**. HPV vaccine is safe. The reactions that people have had after the HPV vaccine have been similar to reactions from other vaccines or medicines, such as pain, redness, dizziness, fainting, nausea, and headache. HPV vaccination is typically not associated with any serious side effects. You can protect the children in your life from this cancer-causing virus by getting HPV vaccine for them. Talk to your doctors about getting HPV vaccine for your kids.

4. Low Emotion and Anti-Organization

31,000 women and men are **diagnosed** with a cancer caused by HPV infection every year in the United States. HPV is transmitted sexually and about 80 million people in the U.S. are affected. HPV caused cancers include but not limited to cervical cancer, anal cancer and oropharyngeal cancer. **However, National Health College of Pediatrics (NHCP) is attacking HPV vaccine by saying that neither boys nor girls should be vaccinated. People in NHCP are not competent, trustworthy and have vested interest**. Their advice is **questioned** by experts and scientists and they should be **criticized**. HPV vaccine is safe. The reactions that people have had after the HPV vaccine have been similar to reactions from other vaccines or medicines, such as pain, redness, dizziness, fainting, nausea, and headache. HPV vaccination is typically not associated with any serious side effects. You can protect the children in your life from this cancer-causing virus by getting HPV vaccine for them. Talk to your doctors about getting HPV vaccine for your kids.

Appendix 2: Questionnaire

Questions	Format
Vaccine Unacceptability (1 item) *Please indicate how much you agree with each of the statement.* -It is better to get the disease and get protected from it naturally than to be vaccinated.	1 (Strongly disagree) to 7 (Strongly agree)
Perceived Knowledge (3 items) *Please indicate how much you agree with each of the statement.* -I know the topic of HPV. -I understand the risks of HPV. -I understand the issue of HPV vaccine.	1 (Strongly disagree) to 7 (Strongly agree)
Safety Concern (3 items, Madhivanan, et al., 2014) *Please indicate how much you agree with each of the statement.* -I am concerned about side effects of HPV vaccinations. -I would feel responsible if anything bad happened because my child got the HPV vaccine. -I am worried about safety of the HPV vaccine.	1 (Strongly disagree) to 7 (Strongly agree)
Perceived Severity (3 items, Witte, 1992)	1 (Strongly disagree) to 7 (Strongly agree)

Please indicate how much you agree with each of the statement. - I believe HPV can be extremely harmful. - I believe that HPV can cause serious health problems. - I believe that HPV caused disease can be extremely harmful.	
Perceived Susceptibility (3 items, Witte, 1992) *Please indicate how much you agree with each of the statement.* - It is likely that my children will get HPV in the future. -My children may be at-risk of getting HPV infection. - It is possible that my children will get HPV caused cancer in the future.	1 (Strongly disagree) to 7 (Strongly agree)
Efficacy (3 items, Madhivanan, et al., 2014) *Please indicate how much you agree with each of the statement.* -I am confident HPV vaccines can have a positive effect on my children's health. -HPV vaccines are effective at preventing diseases. -Having the vaccination would be a good way to protect my children against HPV caused cancer.	1 (Strongly disagree) to 7 (Strongly agree)
Discrete Emotions (20 items, Buck,et al., 2004) *Please indicate your typical feelings to the message you have read.* -Fearful	1 (Not at all like me) to 7 (Just like me)

-Angry -Sympathetic -Sad -Scornful -Confident -Guilty -Irritated -Worried -Safe -Scared -Pity -Indignant -Compassionate -Contemptuous -Remorseful -Disrespectful -Regretful -Sorry -Protected	
What is your biological sex?	Male Female

What is the highest level of school you have completed or the highest degree you have received?	Less than high school degree High school graduate (high school diploma or equivalent including GED) Some college but no degree Associate degree in college (2-year) Bachelor's degree in college (4-year) Master's degree Doctoral degree Professional degree (JD, MD)
How would you describe your ethnicity? You can choose one or more.	Caucasian Hispanic African American Native American Asian American

	Asian-Pacific Islander Other
What is your age?	25-34 35-44 45-54 55-64 65+
How many boys do you have?	
How many girls do you have?	
Here is a 7-point scale on which the political views that people might hold are arranged from extremely liberal (left) to extremely conservative (right). Where would you place yourself on this scale?	1-7