

Influenza Surveillance and Vaccination Practices on a University Campus:
Evidence from the *OutSmart Flu Surveillance & Research Initiative*

by

Christine P. Muganda

A dissertation submitted in partial fulfillment of
the requirement for the degree of

Doctor of Philosophy

(Population Health)

at the

UNIVERSITY OF WISCONSIN-MADISON

2015

Date of final oral examination: 12/3/2014

The dissertation is approved by the following members of the Final Oral Committee:

Ajay Sethi, Associate Professor, Population Health Sciences

Ronald Gangnon, Associate Professor, Biostatistics & Medical Informatics and
Population Health Sciences

Sarah Van Orman, Executive Director, University Health Services

Shawnika Hull, Assistant Professor, Journalism & Mass Communication

Ryan Westergaard, Assistant Professor, Medicine

© Copyright by Christine P. Muganda 2015

All Rights Reserved

For my grandfather, Reverend Josiah Muganda, whose dedication to education for social benefit continues to transcend generations. Babu yangu, wewe ni mwalimu na mfano.

Acknowledgements

This dissertation was funded in part by a grant provided by the Robert Wood Johnson Foundation Health & Society Scholars programs at the University of Wisconsin-Madison. I am truly grateful for the opportunity these funds provided to pursue the unique and exciting experience of conducting a research study from design through analysis.

I am delighted to have opportunity to here express gratitude to the many contributors who have both formally and informally provided support for this work. It is stunning to pause at the end of such a journey and recount the generosity of my extensive support system.

I would like to express appreciation for my advisor Dr. Ajay Sethi. Without your supervision and involvement, the data collection for this project would have been impossible, and I am very grateful for the transferable skills I have gained through the execution of *OutSmart Flu*. I have a special appreciation for your encouragement and support during the events I now refer to as “qualifiers 2.0” and “the traumatic brain injury of 2013.” Your investment in both of these battles was key in the eventual positive outcome for my academic career. Thank you.

I feel privileged to have found such diversity, expertise, and support within my committee, and I would like to extend my gratitude to each member. Dr. Ron Gangnon, Dr. Shawnika Hull, Dr. Sarah Van Orman, and Dr. Ryan Westergaard, thank you for your enthusiastic willingness to address my questions and for providing invaluable input during the design and execution of the *OutSmart Flu* project. Because of you, I am able

to count my preliminary exam among the highlights of my graduate career; I will not soon forget the feeling of leaving that experience – with new ideas and questions burning and renewed courage, believing that I could grow into a productive researcher. I do look forward to the next time we meet together.

I am grateful for the influence of Alisa Santiesteban and Craig Roberts of University Health Services, and their willingness to share valuable expertise. Thank you also to Naomi Lundman for contributing time and attention to detail during the shaping of *OutSmart Flu*. I would also like to thank each of the *OutSmart Flu Street Team* members. Special thanks to Jessica and Eilisha who demonstrated remarkable dedication and contributed valuable insight to the success of this project.

I am incapable of giving adequate thanks to my family members who have been continuously understanding and self-sacrificing in their support of my educational pursuits. Daddy and Mom, thank you for teaching me to love learning and to value educational opportunities. You have been generous in your faithful willingness to cross state lines just to spend a few hours together, and in never expressing anything but encouragement when I pull out the laptop at family events; I am so grateful to you. Much love to my sisters, who have also been the best of friends: thank you for the generosity you display in giving your own limited time to provide the cheer that only sisters can.

And to Justin, who sacrificed sleep and embraced a role as a sounding board and proofreader, willingly re-living the hardships of dissertating immediately after completing his own PhD. Thank you, I could not ask for a more supportive, patient partner. The impressiveness of your selflessness is rivaled only by your mysterious

ability to consistently identify whether, on a bad day, a suggestion for exercise or chocolate will be more welcomed – sometimes I think that this gift has preserved us both.

I would like to thank my friend and roommate Abbey for being a living reminder that writing must be celebrated, never tiring of addressing my serial abuse of the semicolon, and ensuring that I stay connected to “real” life.

Finally, I feel overwhelmingly blessed by all of the friends who have made special efforts to support me during my PhD work: Sam, Christina, Stephanie, Whitney, Larry, Dola, Dorothy, Jes, and my many wonderful cousins. You have each introduced a unique joy into this process. A very special thank you to my comrades in the Department of Population Health Sciences: Marissa, Jill, Jackson, Jason, Erika, Megan, Vijay, and Ifna. I am honored to have built friendships with such gifted colleagues and I look forward to working alongside each other in careers full of population health impact.

Table of Contents

Acknowledgements	ii
List of Tables	ix
List of Figures	xi
Abstract	xii
Chapter 1: Introduction	1
Motivation	1
The <i>OutSmart Flu</i> Approach	2
Data & Aims	3
Aim 1.....	4
Aim 2.....	4
Aim 3.....	5
Dissertation Composition	6
Chapter 2: Literature Review	7
Influenza	7
Vaccination	10
Theoretical Models for Behavioral Change	12
The Health Belief Model.....	12
Conceptual Model for Influenza Vaccination.....	13
Surveillance	14
Smartphones for Surveillance and Behavioral Change	17
Significance	19

Chapter 3: <i>OutSmart Flu</i>	23
Overview	23
The <i>OutSmart Flu</i> Smartphone app	23
app Specifications & Survey Management	23
Study Population, Recruitment & Enrollment.....	24
Survey Instruments.....	26
Interventions.....	28
Daily Processing of Symptom Reports.....	29
Ethical Considerations	30
Campus-wide app Evaluation Survey	31
Chapter 4: Influenza Vaccination Coverage among University Students.....	36
Introduction	36
Influenza and Vaccination in University Student Populations.....	36
Methods	38
Study Design and Eligibility.....	38
Data	39
Statistical Analysis.....	39
Results	41
Discussion	44
Limitations and Potential Biases	47
Conclusion.....	48
Chapter 5: Determinants of Influenza Vaccination in a University Campus	
Population: A Health Belief Model Approach	59
Introduction	59

Seasonal Influenza and Vaccination.....	59
Health Belief Model	60
Conceptual Model for Influenza Vaccination	61
Methods	62
Study Design and Eligibility.....	62
app-administered Survey Instruments.....	63
Statistical Analysis	65
Results	66
Discussion	69
Introduction	85
Smartphones and Current Usage.....	87
Methods	88
Study Population, Recruitment & Enrollment.....	89
app Specifications & Survey Management	89
Daily Processing of Symptom Reports.....	90
ILI Case Definition.....	91
ILI Rate Comparisons	91
Statistical Analyses	91
Results	92
Discussion	95
Chapter 7: Synthesis	110
Summary	110
Surveillance	110
Vaccination.....	111
Intervention.....	112

Conclusion	113
References	115
Appendices	126
Appendix A: OutSmart Flu app content	126
Appendix A.1: Orientation Survey	126
Appendix A.2: Baseline Research Survey.....	131
Appendix A.3: Follow-up Research Survey	146
Appendix A.4: Symptom Report Survey	158
Appendix A.5: Flu Prevention Survey.....	161
Appendix B: App Evaluation	163
Appendix B.1: Campus-wide App Evaluation Survey	163
Appendix C: Supplemental material for Chapter 4	172
Appendix C.1: Cronbach’s alpha Coefficients for Measured Health Belief Model Domains as Measured at Baseline (N=589).....	172
Appendix D: Supplemental material for Chapter 5	175
Appendix D.1: OutSmart Flu (OSF) Demographics Compared at Baseline and Follow-up.....	175
Appendix D.2: Aggregate Weekly Surveillance Rate Estimates from University SHC and OutSmart Flu (OSF) Data.....	177
Appendix E: Supplemental Material for Chapter 6	178
Appendix E.1: Interventional potential of the OutSmart Flu app.....	178

List of Tables

Table 1. <i>OutSmart Flu</i> app Features	32
Table 2. Recruitment Methods	33
Table 3. Comparison of Demographic Information for University Population and Study Population (N= 2,022)	50
Table 4. Demographics Associated with First-time Vaccination	51
Table 5. Characterization of Study Population by 2013-14 Vaccination Status	52
Table 6. Demographic Factors Associated with Receipt of the 2013-24 Seasonal Influenza Vaccine in Multivariable Logistic Model.....	54
Table 7. Location of Vaccination among Vaccinated Students (N=1,205).....	55
Table 8. Characterization of Vaccinated Students by Vaccination Location	56
Table 9. Demographic Factors Associated with Location of 2013-14 Vaccine Receipt in Multivariable Logistic Model.....	58
Table 10. Demographic Comparison of Undergraduate Student Population and Undergraduate <i>OutSmart Flu</i> app Users	75
Table 11. Demographic Distributions of <i>OutSmart Flu</i> Users* (N=787)	76
Table 12. Factors Associated with Vaccination Decision as Identified by the Health Belief Model	78
Table 13. Perceived Benefits and Barriers to Vaccination	79

Table 14. Cues to Action Summarized According to Themes among Respondents (N=167)	80
Table 15. Barriers to Vaccination as Perceived at Baseline among Participants with Vaccination Intention Change.....	81
Table 16. Cues to Action Reported among Participants with Vaccination Intention Change.....	82
Table 17. Comparison of Demographic Information for Undergraduate University Population and <i>OutSmart Flu</i> Undergraduate Population	99
Table 18. Demographics of Study Participants according to Reporting Status.....	100
Table 19. Frequency of Symptoms Included in Reports of Illness.....	102
Table 20. Logistic Regression of Grouped SHC Surveillance Data.....	103
Table 21. Participant-reported impact and acceptability of <i>OutSmart Flu</i>	178

List of Figures

Figure 1. Influenza-specific Health Belief Model	22
Figure 2. Conceptual Model of Factors Relating to Influenza Vaccination	22
Figure 3. Timeline of <i>OutSmart Flu</i> Components by Calendar and CDC Week	35
Figure 4. Conceptual Model of Factors Relating to Influenza Vaccination	83
Figure 5. User Engagement with <i>OutSmart Flu</i> app Components	84
Figure 6. Timeline of <i>OutSmart Flu</i> Components by Calendar and CDC Week	104
Figure 7. <i>OutSmart Flu</i> Symptom Report app Screens	105
Figure 8. Rates of ILI-specific Symptoms among <i>OutSmart Flu</i> Symptom Reports.....	106
Figure 9. Symptom Reports Submitted to <i>OutSmart Flu</i> during 2013-14 Influenza Season	107
Figure 10. Reports of Illness Submitted to <i>OutSmart Flu</i> during 2013-14 Influenza Season.....	107
Figure 11. Rates of ILI by Date of Detection for Clinic-based and <i>OutSmart Flu</i> (OSF) Surveillance	108
Figure 12. ILI Rate Threshold for Outbreak Detection at 80% Power by Number of Unique <i>OutSmart Flu</i> Reports per Week ($\alpha=0.05$ for all sample size calculations).....	109

Influenza Surveillance and Vaccination Practices on a University Campus:
Evidence from the *OutSmart Flu Surveillance & Research Initiative*

Christine P. Muganda

Under the supervision of Associate Professor Ajay K. Sethi

At the University of Wisconsin-Madison

Abstract

On university campuses, shared living and learning spaces create opportunity for influenza and influenza-like illness (ILI) to spread rapidly among students, resulting in significant effects on academic performance, absences from work and class, as well as increased antibiotic use and burden on university student health centers. Despite the heightened risk of influenza within this population, vaccination rates among university students continue to be low. Surveillance data contribute essential guidance in the development and implementation of influenza prevention and control programs. The current surveillance system has several challenges including a reporting lag, which may prevent timely detection of early outbreak signs, and underrepresentation of milder cases of ILI. The purpose of this dissertation is the development, pilot implementation, and evaluation of a smartphone app for surveillance and intervention research, as informed by the Health Belief Model. Findings of this research suggest that vaccination rates on university campuses may be higher than previously estimated, although still well below levels essential for the support of herd immunity within the population. Results suggest opportunities for stimulation of behavior change in this population. *OutSmart Flu*

introduced a novel use of the smartphone app, which allowed for the capture of salient cues to action, and the characterization of important barriers and benefits influential to the vaccination decision within this population. No statistically significant difference in signal was found between *OutSmart Flu* surveillance data and that of established surveillance systems. Timing and characteristics of the 2013-14 influenza seasons did not present opportunity for practical evaluation of *OutSmart Flu* potential for outbreak detection. More research is needed to determine the potential for a smartphone app to be used successfully for ILI surveillance in a university setting. Purposeful incorporation of smartphones for surveillance, research, and public health interventions can be useful on university campuses; however, theoretical foundations and alignment with established public health goals are essential for the success of these initiatives.

Chapter 1: Introduction

Motivation

Epidemics of influenza and influenza-like illness (ILI) occur annually, varying in an unpredictable fashion in terms of timing and severity. For affected individuals, respiratory symptoms range from moderate to severe and complications of the infection may be fatal. University students form a unique high-risk subpopulation due to shared living and learning spaces, which create an environment that increases the transmissibility of ILIs.

The ubiquity of smartphones on university campuses creates a unique opportunity for a smartphone-based ILI surveillance tool, which may have potential to improve timeliness and sensitivity of syndromic surveillance for ILIs within this population. In addition to the possible address of surveillance challenges, high rates of smartphone ownership and frequent use patterns assumed by this demographic may present further opportunities for novel approaches to improve and protect health. Further, the personal nature of these devices creates opportunity for health behavior interventions having high penetrance, such that university students comprise a population especially well situated for impact via smartphone.

Current challenges to influenza prevention and surveillance on university campuses (discussed in Chapter 2) in conjunction with the opportunities presented for smartphone-based approaches, has led to the evolution of two research questions addressed in part by this dissertation. Primarily, this work investigates the potential for a smartphone app to be used to detect a flu epidemic in a university student population and secondarily examines

how a smartphone app might be able to measure and possibly impact flu prevention behaviors within this population. The *OutSmart Flu Surveillance & Research Initiative* was developed in response to these research questions.

The *OutSmart Flu* Approach

The purpose of this dissertation is the development, pilot implementation, and evaluation of a novel smartphone app for influenza surveillance and intervention research. The *OutSmart Flu* app provides university students with an interface to report real-time presence or absence of symptoms indicative of ILI, view updated ILI campus surveillance trends (as determined by *OutSmart Flu* user symptom reports), access influenza prevention tips, and participate in influenza-related research surveys. The research component of the *OutSmart Flu* app creates opportunity for the longitudinal measurement of factors associated with influenza vaccination, as informed by health behavior theory.

The scope of this project is broad – *OutSmart Flu* aimed to inform best practices for the use of smartphones as a means to collect and disseminate health information among university students, as well as measure the potential for a smartphone to impact health behaviors. The data collected through these methods are able to inform health behavior research, public health interventions and provide direction for future smartphone-based research.

At the conception of this project, *OutSmart Flu* was designed as a randomized intervention trial to examine the impact of campus-level surveillance feedback (supplied by symptom reports of app users) on the adoption and use of the smartphone app for the

reporting of ILI symptoms and on undergraduate student engagement in influenza prevention behaviors. A key component of this study design was the randomization of participants between two groups to test the hypothesized association between surveillance feedback and the use and effects of the app. Users were initially randomized upon enrollment to one of two treatment arms. Both treatment arms received access to all app features, including the symptom report survey; upon survey completion however, the report of campus-level ILI activity was delivered only to the intervention arm; the control arm received no such report.

After receiving multiple requests from control arm participants to “modify” the app by adding a report such as the one being delivered to the intervention arm, the study team determined that the best decision to maximize user benefit, retention, and engagement was to migrate all members of the control arm to the intervention arm. One month after the app deployment, randomization ceased and the campus-level ILI activity was made available to all *OutSmart Flu* users. This change in the study design caused a shift in the focus of the study towards understanding app surveillance potential and examining health behaviors related to ILI prevention.

Data & Aims

Data used for this body of work were collected from a series of app-based surveys and a web-based, app-evaluation survey. The app-based surveys included single-completion baseline and follow-up surveys, and also multiple-completion flu prevention and symptom reporting surveys. In addition, app users were asked to complete a user profile consisting of demographic information. The web-based, app-evaluation survey was administered to all undergraduate students, regardless of app usage, and is referred to

as the campus cross-sectional survey. The surveys are provided in Appendices A and B, with methods described in detail in Chapter 3. The datasets are here associated with the appropriate aims.

Aim 1

Current estimations of university-specific influenza vaccination rates are based on the number of vaccinations delivered to students through the student health center (SHC), and supplemented, when available, by self-reported vaccination status as reported in student medical histories (Sarah Van Orman MD, personal communication, October 31, 2014); the accuracy of these estimates is dependent on the unmeasured prevalence of off-campus vaccination.

Aim 1 of this dissertation is to characterize influenza vaccination practices in a population of university students through examination of the following measures: prevalence of the 2013-14 vaccine, location of vaccine receipt (on-campus vs. off-campus), and factors associated with or influencing the vaccination decision. It is hypothesized that campus vaccination rates based solely on SHC records may be underestimated due to vaccinations occurring off-campus.

To address Aim1, data were collected via the campus cross-sectional survey, which was web-based and did not require participation in the *OutSmart Flu* app study for inclusion.

Aim 2

The Health Belief Model provides a framework to conceptualize factors influential in the vaccination decision. While the components of the Health Belief Model have been

shown to correlate with influenza vaccination compliance (Green, 2000; Larson et al., 1982); the description of the relationship between these components is vague.

This study seeks to clarify relationships between specific components of the Health Belief Model in the context of influenza vaccination. Aim 2 of this dissertation is to identify the relative importance of specific benefits and barriers to vaccination as perceived by vaccinated and unvaccinated subpopulations, and to capture and characterize cues to action influential in the vaccination decision. Aim 2 is exploratory in nature; therefore no a priori hypotheses were made.

To accomplish Aim 2, the *OutSmart Flu* app was employed for data collection. Data were collected via the baseline and follow-up surveys, with cues to action captured through the flu prevention surveys.

Aim 3

Aim 3 of this dissertation is to summarize findings from the 2013-14 *OutSmart Flu* influenza surveillance smartphone app study, in regards to correlations of estimated ILI rates with those of other established surveillance systems and best practices for surveillance of ILI by smartphone in a university student population.

Findings from the *OutSmart Flu* surveillance study are expected to correlate with SHC surveillance, and decrease reporting lag-time. Data for Aim3 were collected via the symptom reporting survey, using available demographic data assembled from the profile, baseline, and follow-up surveys.

Dissertation Composition

This dissertation is organized into seven chapters. Chapter 2 provides background and justification for the *OutSmart Flu* project through the review of literature relevant to impact and natural history of influenza and ILIs, transmission dynamics and susceptibility among university students, public health interventions and surveillance practices, health behavior theory, and current trends in mobile health (mHealth) and the culture of smartphone use within university student populations. Chapter 3 details the study design and methods used in the execution of *OutSmart Flu*. Chapters 4, 5, and 6 are manuscripts individually addressing the specific aims of the dissertation. Chapter 7 provides synthesis for the findings of this dissertation and directs discussion of the contributions of this body of work and implications for public health and for future research.

Chapter 2: Literature Review

Influenza

Influenza is an acute respiratory infection caused by influenza viruses. These viruses are classified into three types; influenza type A and type B are most common, with type C occurring much less frequently (World Health Organization, 2014). Type A influenza viruses also affect non-human mammals and birds; however, influenza type B and type C viruses predominantly affect humans. Influenza viruses are enveloped RNA viruses belonging to the orthomyxovirus family; they carry two important glycoproteins on their exterior: the rod-shaped hemagglutinin and the mushroom-shaped neuraminidase. Hemagglutinin is the viral component responsible for mediating cell entry. Antibodies formed against hemagglutinin are effective in preventing infection and neutralizing the virus. Neuraminidase is an enzyme used by the virus to spread between cells; antibodies formed against neuraminidase are able to reduce the severity of the illness (Treanor, 2004).

Influenza has been established as a vaccine preventable disease (U.S. Department of Health and Human Services, 2010) and a solid immunity may also be induced by infection, however, the constant mutation of influenza viruses presents a major challenge to influenza prevention. Antigenic variations undergone by influenza viruses are classified as either antigenic drift or antigenic shift. Antigenic drift occurs in both type A and type B influenza viruses and is a phenomenon caused by small genetic changes introduced by the process of viral replication. These mutations may be slight enough to allow an effective immune response through recognition of a mutated virus by an

immune system previously exposed to a similar strain. However, sufficient accumulation of small genetic mutations may result in phenotypic changes large enough to inhibit binding of established antibodies, resulting in a viral strain able to successfully circumvent the immune system. Antigenic shift is a more dramatic, abrupt phenotypic change resulting in the replacement of viral surface glycoproteins (i.e. hemagglutinin or neuraminidase) with subtypes novel to the human virus. Because antigenic shift occurs through the recombination of multiple (often non-human) viruses, this type of variation is decidedly more rare, and can be much more dangerous than antigenic drift. For antigenic shift to occur, two influenza viruses must independently co-infect a single host such that viral mixing may occur through reassortment of genomic segments. The novel virus created during this process may have full virulence for humans and foreign surface glycoproteins (usually animal host virus hemagglutinin) for which the human population lacks immunity (Zambon, 1999). Due to lack of immunity in the population, viruses created by antigenic shift may have pandemic potential.

Within a population, influenza spreads through respiratory transmission; this includes direct contact (i.e., mouth-to-mouth, or hand-to-mouth) with an infected individual, contact with contaminated objects such as elevator buttons or doorknobs, and inhalation of aerosolized viral particles. For most healthy adults, the incubation period for influenza is two days, and an infected individual may begin transmitting the virus one day prior to manifestation of symptoms, with transmission continuing five to seven days after onset. Influenza symptoms usually appear suddenly and may include fever, chills, cough (usually dry), sore throat, runny or stuffy nose, muscle or body aches, fatigue, and possibly vomiting or diarrhea. The average length of recovery ranges from a few days to

two weeks; with fever and body aches lasting three to five days, and the cough and fatigue continuing longer (Centers for Disease Control and Prevention, 2014a).

Symptom-based, clinical diagnosis has been shown to be highly predictive of laboratory confirmed influenza during periods of high influenza prevalence (positive predictive value: 79–87%; negative predictive value: 39–75%) (Gavin and Thomson Jr., 2003).

During times of peak influenza transmission, patients presenting with a fever over 100°F with a cough or sore throat in the absence of a known cause other than influenza are diagnosed with an influenza-like illness (ILI) according to the case definition provided by the Centers for Disease Control and Prevention (CDC). This syndromic surveillance is used in conjunction with laboratory confirmed surveillance of circulating viruses to provide a representation of influenza activity in the United States.

Epidemics of seasonal influenza are serious cause for public health concern both in terms of individual symptom severity and in breadth of population impact. Each year in the United States, ILIs are associated with increased burden on healthcare systems, lost work time and decreased productivity, and in some cases, complications of the infection may lead to early mortality (Centers for Disease Control and Prevention, 2014a; Klepser, 2014). Influenza burdens the general population with a spectrum of mild to moderately severe acute respiratory illness; it has been estimated that 30% of acute respiratory infections in young adults are caused by influenza (Carrat et al., 1999; Nichol et al., 2005). Although the high-risk population is often equated with the elderly (Thompson et al., 2009), individuals in younger age groups are also vulnerable to complications, especially in the case of immunodeficiency and co-morbidities such as asthma, diabetes, heart disease, and chronic bronchitis (American Lung Association, 2010; World Health

Organization, 2014). In addition to the possibility of complications arising from exacerbation of underlying conditions, certain circulating viral strains have been found to demonstrate higher virulence in young adults as compared to typical years (American Lung Association, 2010).

On university campuses, shared living and learning spaces create opportunity for ILIs to spread rapidly among students, resulting in significant effects on academic performance, absences from work and class, as well as increased antibiotic use and burden on university SHCs (Uddin et al., 2010; Nichol et al., 2005). For university students, the seasonality of influenza epidemics poses an additional threat to productivity. The timing of increased influenza activity varies between years, but in the northern hemisphere, the season generally overlaps with the majority of the academic year, and runs from October to May with peak activity frequently occurring in February (Centers for Disease Control and Prevention, 2014a). Although occurrence of ILI varies widely between seasons within all populations, university students are at notably higher risk compared to other young adults. Studies have found the incidence of ILI among healthy adults to range between 2%-10% in non-pandemic years (Bridges et al., 2002; Eysenbach, 2006). In contrast, among university students, incidence of ILI has been found in excess of 25% (one study reported 36.7% incidence among university students during the 2002-03 influenza season) (Pons et al., 1980; Sobal and Loveland, 1982).

Vaccination

The CDC Advisory Committee on Immunization Practices (ACIP) recommends routine annual influenza vaccination for all persons aged six months or older, as the most effective influenza prevention tactic (Grohskopf et al., 2014). Two types of influenza

vaccines are currently licensed for use, the first containing live attenuated influenza virus (LAIV) and the second containing inactivated influenza virus (IIV). The contents of these vaccines are reviewed annually to account for changes in the dominant circulating strains. Vaccine efficacy is variable across years dependant on a variety of factors including the similarity between circulating strains and those included in the vaccine. The IIV vaccine has been found to have 70–90% efficacy in a typical year (Monto et al., 2009; Nichol et al., 2008; Ohmit et al., 2006), and research has shown LAIV to perform with similar or lesser efficacy as compared to IIV in adults (Ambrose et al., 2011; Monto et al., 2009; Ohmit et al., 2006; Ohmit et al., 2008). Early widespread vaccination, implemented along with other influenza prevention behaviors, is key to effective interruption of influenza transmission (Suess et al., 2012). Healthy People 2020’s target goal for vaccination of adults aged eighteen to sixty-five is 80% for the annual influenza vaccine (U.S. Department of Health and Human Services, 2010).

The rate of vaccination among university students continues to be low despite the heightened risk of influenza within this population (Ramsey and Marczinski, 2011; American College health Association, 2012). The Healthy People target of 80% is a notable increase for university campuses where influenza vaccination rates were estimated in 2010 to be 33.9% using survey data (American College Health Association, 2012). The target goal set by American College Health Association’s (ACHA) Healthy Campus 2020 is a 10% increase in influenza vaccination rates on university campuses to reach 43.9% by 2020 (American College Health Association, 2012). University-specific prevalence estimates of influenza vaccination are based on the number of vaccinations delivered to students through the SHC, and supplemented by self-reported vaccination

status as reported in student medical histories (Sarah Van Orman MD, personal communication, October 31, 2014); the accuracy of these estimates is dependent on the unmeasured prevalence of off-campus vaccination

Theoretical Models for Behavioral Change

The status of influenza as a vaccine preventable disease (U.S. Department of Health and Human Services, 2010) prescribes employment of (preventative) health behavior theory in the study of actions and attitudes surrounding individual influenza prevention practices. Kasl and Cobb (Kasl and Cobb, 1966) have defined a health behavior as “any activity undertaken by a person who believes himself to be healthy for the purpose of preventing disease or detecting disease in an asymptomatic stage.” This class of behavior is contrasted with activities undertaken for the purpose of health improvement by those believing themselves to be ill.

The Health Belief Model

The Health Belief Model (HBM) was developed for the purpose of conceptualizing health behavior (Rosenstock, 1974) and is a popular framework for studies addressing influenza vaccination compliance. The major components of the HBM are perceived severity and susceptibility, perceived threat, perceived benefits and barriers, and cues to action;¹ the association between each component and the behavior is affected by

¹ The HBM includes a self-efficacy component, which was added to the original model to expand application from single event prevention behaviors to include long-term behavior modifications. Self-efficacy is an element borrowed from social cognitive theory, which refers to an individual’s belief about their capability to perform a behavior (Bandura, 1994). Due to the nature of influenza vaccination, this work omits self-efficacy from the conceptual model and does not include a detailed discussion of this construct.

modifying factors such as sociodemographics and knowledge about the disease (Rosenstock, 1974) (Table 1). In the context of influenza vaccination:

Perceived threat is determined by an individual's perception of influenza severity and the individual's perceived susceptibility to influenza. An individual who perceives influenza to be a severe disease, with serious consequences for health and function, will be more likely to engage in prevention practices such as vaccination. In like manner, individuals perceiving themselves at risk for influenza infection will be more likely to seek vaccination due to perceived susceptibility.

Perceived benefits and barriers capture an individual's perception of vaccine efficacy for influenza prevention, minus the individual's assessment of cost associated with vaccination. An individual perceiving the benefits of vaccination, as an effective means of decreasing influenza risk, to outweigh the perceived cost (e.g., side-effects, needle-phobia, inconvenience, etc.) will be more likely to comply with vaccine recommendations.

Cues to action may come from physician recommendations, the media, observation of an ILI, or other stimulus serving as a catalyst for action to seek vaccination.

Conceptual Model for Influenza Vaccination

The sole focus of the HBM on perceptual and circumstantial factors has gained some criticism (Fishbein and Ajzen, 1972; Montano, 1986), asserting that the model is “more concerned with the subjective state of the individual than with history or experience” (Davidhizar, 1983). This charge may be warranted in the case of influenza vaccination compliance, as prior vaccination history has been found to be strongly associated with

future vaccination (Bödeker et al., 2014; Naleway et al., 2014). Regardless of these critiques, elements of the HBM have been shown to correlate with influenza vaccination compliance (Green, 2000; Larson et al., 1982); therefore, the a modified HBM incorporating history and experience is proposed as a conceptual model for this research (Table 2).

Surveillance

Surveillance data provide an essential guide in the development and implementation of influenza prevention and control programs. Currently, the U.S. Outpatient Influenza-like Illness Surveillance network (ILINet) serves as the gold standard for influenza surveillance in the United States. ILINet is collaboration between the CDC and over 2,900 outpatient clinics distributed across the nation responsible for conducting syndromic surveillance for influenza. As a condition for inclusion, ILINet surveillance data requires an outpatient visit with symptoms satisfying the CDC case-definition of ILI (i.e. fever over 100°F with cough and/or sore throat in the absence of an alternate diagnosis) (Centers for Disease Control and Prevention, 2014b). Challenges to this system include the ten- to fourteen-day reporting lag, which may prevent timely detection of early outbreak signs, and underrepresentation of milder cases of ILI, introducing potential overestimations of severity of circulating strains due to selective reporting of cases (Garske et al., 2009) .

Alternatives to the ILINet syndromic surveillance system have been explored to address these shortcomings. Proposed sources of influenza surveillance data have included emergency department and absenteeism reports, health advice calls, web queries, and pharmaceutical sales (Heffernan et al., 2004; Dailey et al., 2007).

Pharmaceutical sales data have been harnessed with some success as a timely alternative to syndromic surveillance systems such as ILINet. Studies have found over-the-counter flu remedy sales to accurately predict physician diagnoses of acute respiratory conditions with a 3-day lead-time (Magruder, 2003), and estimates of influenza rates generated from flu prescription sales correlate closely with those of ILINet and other established surveillance systems (Patwardhan and Bilkovski, 2012). However, these methods raise concern due to biased detection of cases according to symptom severity and socioeconomic status, as well as potential loss of specificity due to self-diagnosis in the case of over-the-counter treatments (Patwardhan and Bilkovski, 2012).

Surveillance systems must strive to optimize the tradeoff between sensitivity and specificity, without substantially burdening public health agencies, or interfering with the duties of healthcare systems. Surveillance systems based on emergency room or clinic visits require additional steps to assemble data into weekly or daily reports to be forwarded to officials, and may become burdensome (Heffernan et al., 2004). Technological advances have simplified these processes and have made collection, processing, transmission, and analysis of surveillance data feasible. Further, systems initially designed for non health-related purposes are producing stores of underused data, which in the most recent decade have begun to be tapped for disease surveillance.

In November of 2008, Google launched an internet-based approach to influenza surveillance: Google Flu Trends (GFT) uses an automated query-selection process to identify ILLI-related searches without requiring the searcher to have any previous knowledge about influenza (Google.org, 2008; Carneiro and Mylonakis, 2009). This aggregate search engine data is then used to detect influenza epidemics and predict

outpatient visits due to ILI. Web queries often occur prior to clinic visits; prompt processing of these queries produced ILI surveillance estimates that consistently preceded CDC reports by one to two weeks in the GFT pilot. An advantage of the GFT approach over ILINet is the extensive availability of search engines, decreasing opportunity for detection bias introduced by clinic-based methods. (Ginsberg et al., 2009). GFT has demonstrated the ability to detect outbreaks seven to ten days earlier than conventional CDC surveillance systems (Carneiro and Mylonakis, 2009), and to produce estimates of ILI rates strongly correlating with ILINet data (Ortiz et al., 2011). GFT may enable timely public health response through early alert in the case of outbreaks; however, researchers caution reliance on GFT in place of local surveillance, as the nonspecific nature of the GFT model causes susceptibility to overestimation (Cook et al., 2011; Eysenbach, 2006; Ginsberg et al., 2009; Olson et al., 2013).

GFT surveillance data is also susceptible to errors introduced by changes in search behavior in response to media and other external events, especially in the case of epidemics when healthy individuals may also be driven to information seeking. In February 2013, GFT was found to be over-reporting rates of outpatient visits for ILI by a factor of two when compared to ILINet data (Butler, 2013; Lazer et al., 2014). A further limitation of the GFT approach is the absence of demographic information, which is helpful for implementation of control and prevention measures. While GFT may be used effectively to detect aberrations and outbreaks, the current algorithms appear inappropriate for the quantitative estimation of influenza rates.

Smartphones for Surveillance and Behavioral Change

The recent advance of smartphones has opened numerous opportunities for novel developments in public health surveillance and intervention. These mobile phones have capabilities beyond standard voice and text communication extending to Internet access, geographical positioning systems (GPS), and computational capacities. The smartphone devices are typically equipped with cameras, recording microphones, large display screens, and personalizable user-settings, allowing the device function to be customized easily to the needs of the user (Boulos et al., 2011). In addition to the extensive capabilities of the smartphone, smartphones in the United States tend to be personal objects accessible by only one individual. Furthermore, owners tend to place a high value on interactions with these devices, carrying them powered-on and on their person at most times (Boschen and Casey, 2008; Patrick et al., 2008). These characteristics of the smartphone provide inexpensive and convenient opportunities to introduce behavioral health interventions that may have the potential for higher penetrance and increased effectiveness in certain populations (Dennison et al., 2013).

mHealth is a field that has expanded rapidly in recent years, keeping pace with the continuous development of new mobile technologies. No standardized definition of mHealth has been developed; the World Health Organization (WHO) has adopted use of the mHealth definition established by the Global Observatory of eHealth as “medical and public health practice supported by mobile devices, such as mobile phones...” (World Health Organization, 2011). Due to the rapid introduction of mHealth initiatives seeking to capitalize on new mobile device capabilities, the number of health-related smartphone apps has increased greatly. However, scientific evaluation of these interventions remains

at a relatively early stage in the published, peer-reviewed literature (Dennison et al., 2013; World Health Organization, 2011). While smartphones pose an exciting opportunity for public health advances, smartphone apps must draw on established health behavior theories, use approaches validated through research, and have content aligned with clinical guidelines in order to be both successful in terms of adoption rates and sustained usage, and impactful for the health of the user and the population (Dennison et al., 2013).

Numerous smartphone apps have been introduced to improve population health indirectly, through data collection for healthcare improvement research or disease surveillance, or directly, as supplements to existing health interventions. The scope of health-related apps is difficult to define due to the lack of documentation of commercial apps in published health literature. Most interventions are short message system (SMS, best known as text messaging) based, but more recent interventions have begun to incorporate other smartphone capabilities. The introduction of apps for health reporting and surveillance has grown quickly in low-income countries as a means for improving timeliness of outbreak detection and has been effective to bridge gaps in health infrastructure not found in higher-income countries (Bastawrous and Armstrong, 2013). Rigorous study of feasibility and acceptability of apps for health reporting for surveillance in the United States is lacking in peer-reviewed literature. Multiple reviews of apps designed for the promotion of behavior change have found available apps to lack features congruent with theory and evidence-based recommendations (Abroms et al., 2011; Breton et al., 2011; Chomutare et al., 2011; Cowan et al., 2013; West et al., 2012). In a qualitative study conducted by psychology researchers in the UK, young adults were

asked to share their experiences and views on various features of a health app. Based on the findings from a series of four focus groups, the researchers found that young adults expressed the importance of features enabling the acquisition of advice; subjects placed value on accuracy of information provided and preferred that information be provided by a legitimate source (Dennison et al., 2013). As the field of mHealth moves forward, much opportunity exists for research to ground app development in theory and harness this promising avenue for effective public health advances.

Of the thousands of available smartphone apps designed for health impact, reviews have found the most successful apps to be those designed for younger and healthier populations (Boulos et al., 2011). This finding is likely due to the comparatively slower adoption of smartphones (and consequently, smartphone-based interventions) by older individuals and those with chronic diseases. Among university students, prevalence of smartphone ownership is continually rising, and increasingly, smartphone owners are utilizing these devices to inform health behavior decisions (Boulos et al., 2011). Based on past trends, 90% of university students in the United States are currently smartphone owners, and that proportion is expected to have reached a plateau (Hanley and Becker, 2012). The prevalence of smartphones and the personal nature of these devices provide significant opportunity to implement convenient and inexpensive health initiatives in university student populations.

Significance

The ubiquity of smartphones on university campuses creates potential for a smartphone-based surveillance tool to not only improve timeliness, but also sensitivity of syndromic surveillance. The personal nature of these devices creates opportunity for

health behavior interventions with high penetrance; university students comprise a population especially well situated for impact via smartphone. The purpose of this dissertation is the development, pilot, and evaluation of a smartphone app for surveillance and intervention research. The *OutSmart Flu* app provides university students with an interface to report real-time presence or absence of ILI symptoms, view updated ILI campus trends, access influenza prevention tips, and participate in influenza-related research surveys. The research component of the *OutSmart Flu* app provides a platform for the longitudinal measurement of factors associated with influenza vaccination, as informed by the HBM. The success of this research would facilitate practical benefits to public health in several key areas as well as significant contributions to mHealth literature.

In the context of influenza vaccination, the HBM provides a guide in the identification of predictors; however, the HBM framework does not characterize relationships between, and relative importance of individual predictive factors. As described by the HBM, benefits, barriers, and cues to action are most proximal to the decision and therefore must be best understood for effective public health interventions. Interventions focused solely on upstream components may be rendered ineffective if barriers are too high, or individuals are not presented with effective cues to actions. Research surveys housed within the *OutSmart Flu* app, provide data enabling the identification of influential benefits and barriers, and provide a unique, near-real time, ability to capture cues to action while still salient.

As demonstrated by the successes of GFT, information-seeking behaviors among ill individuals can lead to symptom reporting. *OutSmart Flu* builds on this phenomenon, not

only providing feedback relating to classification of symptoms according to the CDC definition of ILI, but also providing information about ILI trends on the campus, as well as influenza prevention education. This approach provides incentive for healthy individuals to interact with the app to seek information through reporting lack of symptoms. The benefit of this system is a denominator for better estimation of campus ILI rates. Additionally, the *OutSmart Flu* approach has potential to improve on the existing campus surveillance system by capturing milder cases of ILI which may never prompt a clinic visit, and improving timeliness through early detection (closer to symptom onset) of cases that may later progress in severity and result in clinic visit.

Beyond novelty and innovation, the *OutSmart Flu* mHealth initiative boasts the particular strength of having been developed to model validated approaches with intentional alignment to clinical guidelines and evidence-based practices. The theoretical foundation and research design of this study ultimately resulted in testable findings generalizable to future mHealth initiatives and informative for influenza-specific interventions for the improvement of health within university student populations.

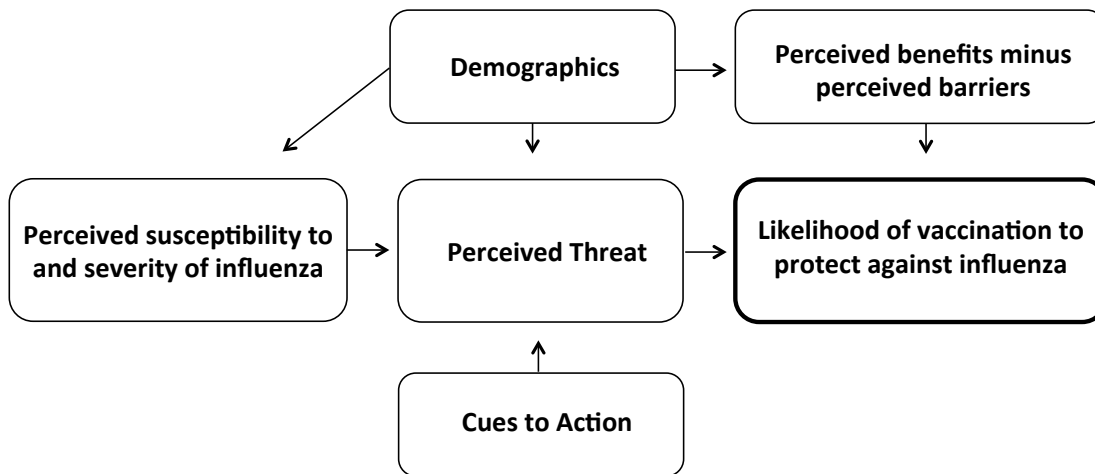


Figure 1. Influenza-specific Health Belief Model

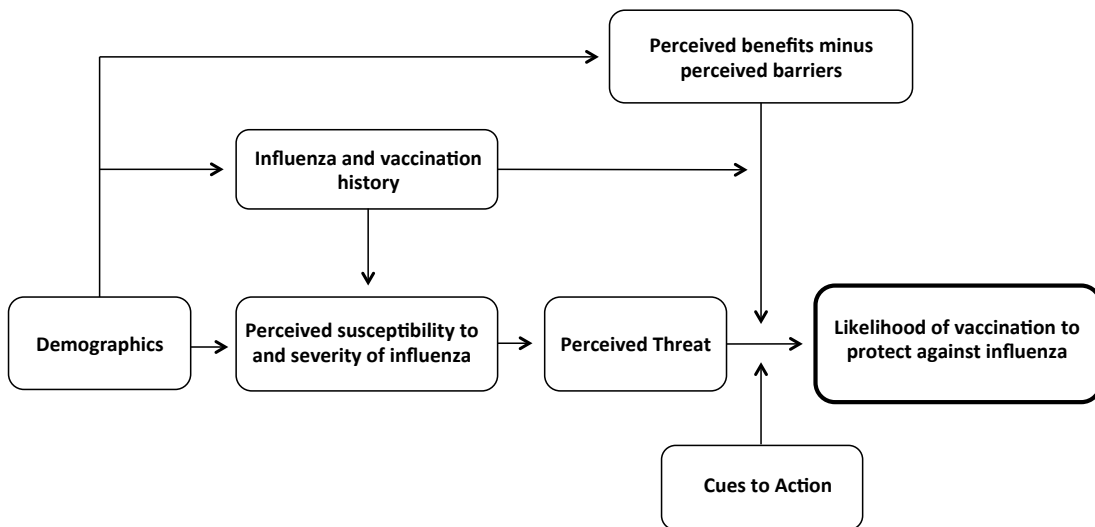


Figure 2. Conceptual Model of Factors Relating to Influenza Vaccination

Chapter 3: *OutSmart Flu*

Overview

Data for this dissertation come from the OutSmart Flu Influenza Surveillance & Research Initiative comprised of a smartphone-based, dynamic cohort study and a follow-up cross-sectional survey. The study was conducted on the University of Wisconsin-Madison campus from September 20, 2013 to May 31, 2014; the study period corresponded to CDC influenza surveillance weeks 39 through 22 of the 2013-14 influenza season (Figure 3). The development of the OutSmart Flu research project was advised by researchers in Population Health Sciences, Journalism & Mass Communication, Biostatistics & Medical Informatics, Infectious Disease Medicine, and physicians and staff of the university SHC. This study was approved by the Institutional Review Board at the University of Wisconsin-Madison (IRB 2013-0658).

The *OutSmart Flu* Smartphone app

An integral component of this project was the *OutSmart Flu* smartphone app used for intervention implementation as well as data collection. The *OutSmart Flu* app provided users with an interface to report real-time presence or absence of ILI symptoms, view updated ILI campus trends, and access influenza prevention tips (Table 1).

app Specifications & Survey Management

The *OutSmart Flu* app was designed as a white label customization of the existing *SurveySwipe* mobile applications survey platform developed by *Survey Analytics* (Survey Analytics LLC, Seattle, WA), and was published simultaneously for Android and iPhone

to the Google Play and iTunes stores with the name ‘OutSmart Flu’ and a description specific to the university initiative. The *SurveySwipe* platform provided the research team with a dashboard that allowed development, deployment, disablement, and tracking of surveys. From the dashboard, surveys could be made available to all study participants, or limited to a specified subgroup; this feature was used for feedback randomization in the initial weeks of the study period. Once deployed, surveys could also be modified from the dashboard; a feature used daily to update the surveillance summaries displayed in response to submission of a symptom report. The *OutSmart Flu* app did not utilize push notifications; iPhone users however, were notified of new survey availability by the red notification badge displayed on the app icon.

Study Population, Recruitment & Enrollment

The *OutSmart Flu* app and associated surveys were made available during the 2013-14 academic year to members of the University of Wisconsin-Madison campus community with a university issued email address. Undergraduate students were targeted for recruitment due to their higher use of the SHC and heightened risk of influenza infection due to close interactions in residence halls and other shared spaces. Students in residence halls and large, entry-level classes were targeted for recruitment on the basis of convenience. To be eligible for inclusion in the *OutSmart Flu* research study, individuals were required to have a university issued email address, be age seventeen or above, and have verified receipt of the study information sheet, and created an *OutSmart Flu* app account using a university issued email address login. Enrollment was rolling throughout the study period; eligible individuals were able to join the study at any time.

Study enrollment and app usage were incentivized by three \$500.00 raffles occurring during the flu season (Raffle dates: October 31, 2013; December 30, 2013; March 13, 2014). Users earned points with various app interactions (Table 1) and total points were displayed on the user's device. Each accumulated point was used as an entry into the cash drawing at the end of each raffle period, and all points were reset following each drawing. Winners were notified via email and asked to make an appointment with the study team to collect the prize in the form of a cashier's check.

This study used a multifaceted approach for participant recruitment (Table 2). Recruitment tactics included an informational website, printed promotional materials, class and residence hall presentations, social media accounts, local and university-related news releases, and word of mouth. Printed promotional materials carried the app logo, study website URL, and raffle information; these materials were circulated on the university campus through residence hall directors, bulletin boards, student mailboxes, and information tables.

A street team of twelve undergraduate volunteers was organized to distribute promotional materials and act as peer liaisons to the undergraduate campus community. Street team members were provided with training sessions and manuals, and were each given a \$50.00 university bookstore gift card in appreciation for their efforts. Street team members and study investigators gave short three- to seven-minute recruiting presentations in classrooms, residence halls, and at student organization meetings. These presentations highlighted the app features, raffle opportunities, and a brief explanation of the importance of influenza surveillance, as well as providing opportunity to distribute printed materials.

Before gaining app access, several registration steps were required, including acknowledging acceptance of the study information sheet and the app terms of service. Following successful account set-up, participants were greeted with an orientation entitled “Welcome to Outsmart Flu” (Appendix A.1). To complete the orientation, participants paged through a series of screens explaining the points system, and various app features, the final page directed users to “get started” by completing the user profile. Throughout the study, periodic newsletters were added to the participant’s survey queue to notify users of notable developments in the flu season (e.g., Wisconsin’s first 2013-14 confirmed influenza case, vaccine match to circulating strands, discovery of overestimation by Google Flu Trends’ algorithm, etc.) as well as *OutSmart Flu* app updates.

Survey Instruments

User Profile

The user profile allowed participants to report demographic characteristics and was available for completion or editing at any time during the study period following participant enrollment. The user profile contained a field for sex, major, date of birth, and housing arrangements (including options for specific residence halls).

Baseline Research Survey

A seven-minute cross-sectional research survey was made available for completion on the app immediately following account setup to collect baseline measurements of factors important to analysis of smartphone-based capture and dissemination of influenza-related health information in this population. The survey contained 29 questions grouped into the following sections: 1) sociodemographic characteristics; 2)

current usage of smartphones for general and health-related purposes; 3) knowledge and attitudes toward influenza and prevention; and 4) influenza-related health history and behavior (Appendix A.2). The baseline survey was set to remain available on the app until completion or study end date.

Follow-up Research Survey

As follow-up to the baseline survey, a second cross-sectional research survey was deployed in March 2014 during week 10 of CDC surveillance. This five-minute survey was made available to all users enrolled at the time of survey deployment, could be completed only once per account, and was set to remain available on the app until completion or study end date. The 32-question follow-up survey measured demographics, and re-assessed knowledge and attitudes toward influenza and prevention, and influenza-related health history and behavior from the baseline survey. The follow-up survey also included questions about the user's experience with and opinions of the app (Appendix A.3).

Symptom Reporting

Symptomatic participants had the option to report symptoms as experienced; similarly, asymptomatic participants had the ability to report absence of ILI symptoms at any time. To conduct syndromic surveillance, *OutSmart Flu* participants were asked to use a brief survey (completion time less than 30 seconds) to report presence or absence of ILI symptoms throughout the influenza season (Appendix A.4). The symptom survey presented participants with a screening question asking, "How are you feeling?" with the option to select either "healthy" or "sick." Users reporting feeling sick were presented with an ILI symptom index and asked to select the symptoms experienced. In accordance

with the ILI definition in use at the SHC, the standard CDC symptom-based case definition of ILI was used (measured fever over 100°F with cough and/or sore throat); participants were asked to enter the highest measured temperature to provide objective symptom assessment of fevers. This survey was available within 24 hours of account set-up to all users and remained available for multiple completions with unlimited frequency for the duration of the study period.

Flu Prevention Survey

Users were asked twice a month to report flu prevention practices during the preceding two-week period. This survey was deployed on the 15th and 30th of each month (exception: February 28th), and remained open until the next deployment (Appendix A.5). Once completed, this survey was removed from the participant's survey queue and remained unavailable until the next deployment date. Average completion time for this survey was less than one minute.

Interventions

Campus-level ILI Report

The health status submitted via symptom report triggered a message with relevant health information (see Appendix A.4 for messages). All users reporting symptoms consistent with the CDC definition of ILI were notified immediately that their symptom report was consistent with ILI, reminded that *OutSmart Flu* does not constitute health care, and were referred to the SHC website for self-care instructions; students with more severe symptoms were instructed to seek healthcare if they would usually do so.

Any symptom report submission (either “healthy” or “sick”) triggered a report of the estimated campus prevalence of ILI as informed by the *OutSmart Flu* community during the past seven days, with the previous week’s SHC weekly report of ILI included for comparison (see Appendix A.4 for template). Thus, users were able to “request” updated surveillance data at any time through the submission of a symptom report. The estimated prevalence was updated daily and reported campus rates were monitored consistently for any significant increase in case numbers.

News Feed

The app news feed was populated with influenza prevention education messaging containing brief, relevant information about consequences and the severity of influenza infection, statistical evidence of prevention behavior efficacy, and descriptions of CDC and SHC recommended prevention behaviors. The content of all *OutSmart Flu* messaging was kept consistent with existing SHC influenza-related messaging on campus.

Daily Processing of Symptom Reports

To update the ILI surveillance summaries, data were downloaded daily from the symptom report survey and manipulated using MS Excel (Microsoft, Redmond, WA). StatTransfer 12 (Circle Systems, Seattle, WA) was used to convert the dataset for Stata version 13.1 (StataCorp, College Station, TX). Stata code was written and executed to determine ILI incidence during the past seven days. The final page of the symptom report survey was updated with the latest ILI summary and the new version was pushed to the *OutSmart Flu* participants.

Ethical Considerations

After downloading the app, potential users were asked to create an account using their university issued email address for login. The account set-up was filtered such that email addresses without a university extension would be refused and the potential user would be reminded that *OutSmart Flu* was available only to members of the University of Wisconsin-Madison campus and prompted again to use a university issued email address as login. This restriction decreased opportunities for creation of multiple accounts by a single user, and for non-campus members to contribute to the ILI surveillance data.

An information sheet detailing the nature of involvement as a participant was emailed to the prospective user preceding study enrollment through completion of account setup. App terms of service included acknowledgment of receipt and understanding of the study information sheet. After acceptance of the terms of service, app users were able to complete account registration and gain access to all app features, including surveys. This double opt-in approach to account setup (i.e., submitting a university issued email address and setting password, followed by confirmation of receipt of study information sheet and acceptance of terms of service) functioned as informed consent.

The study information sheet informed potential users of data confidentiality; the option for self-disenrollment through app uninstallation at any point during the study; and that *OutSmart Flu* was not intended to provide a substitute for seeking healthcare. In addition to the survey data, the *OutSmart Flu* app had capabilities to collect device-specific user and location data; users were given the option to disable the location services. During the study, encrypted data were stored within a secure, HIPAA-compliant, cloud-based infrastructure owned by *Survey Analytics*.

All influenza-related messaging (i.e., newsfeed content and symptom report feedback) were kept consistent with existing SHC influenza-related messaging on campus and were approved by SHC, with the intent to inform students without raising undue alarm.

Campus-wide app Evaluation Survey

An online, cross-sectional, 61-item survey (Appendix B.1) was developed to evaluate the impact of the *OutSmart Flu* project and administered campus-wide on April 18, 2014 (CDC surveillance week 16). This survey included questions regarding familiarity with the *OutSmart Flu* initiative; influenza knowledge and beliefs; influenza history and prevention practices; and demographics. The questionnaire was pre-tested on student volunteers for readability, and clarity of meaning and instructions. *Qualtrics* survey software (Qualtrics, Provo, UT) was used to develop, distribute, and administer the survey. Individuals having a university issued email address were eligible for inclusion if they reported undergraduate student status, and were seventeen years of age or older at the time of survey completion. Survey respondents were eligible regardless of use of the *OutSmart Flu* app. Participants were offered the opportunity to enter a raffle to win one of eleven cash prizes ranging from \$25 to \$100 as incentive for participation.

Table 1. *OutSmart Flu* app Features

Feature	Components/ Description
Profile	Available immediately upon account creation with editing capabilities
Surveys	<ul style="list-style-type: none"> • <i>OutSmart Flu</i> orientation – available upon enrollment; single completion • Baseline research – available upon enrollment; single completion • Symptom report – available within 24 hours of enrollment; unlimited completion • Flu prevention – available for single completion on the 15th and 30th of each month following enrollment during the study period • Newsletters – periodic summaries of flu season progression and app updates • Follow-up research – available March 2014 to all current users; single completion
News Feed	Populated with flu prevention tips consistent with existing SHC messaging on campus
Rewards	<p>Points accumulated through app interactions and counted as raffle entries:</p> <ul style="list-style-type: none"> • Welcome to <i>OutSmart Flu</i> orientation – 10 pts • Completion of profile – 10 pts • Symptom report submission – 1 pt per report per day • Completion of baseline research survey – 50 pts • Flu prevention survey – 10 pts per each • Completion of follow-up research survey – 50 pts
Refer-a-friend	Option for app user to send personalized form letter via the mail client to invite select contacts to download the app and join the study.
Send feedback	Option for app user to contact the study team and the app developers via email.

Table 2. Recruitment Methods

Recruitment Tool	Description	Venue/ Target Audience	Execution Dates
Posters and fliers	8.5x11" color flyers with study description printed on reverse 11x17" single-sided color posters Both designs included "Get the app, not the flu!" slogan, app logo, and website URL.	<ul style="list-style-type: none"> • Academic buildings • Residence halls • Student mailboxes • Campus bulletin boards 	Sept 2013 – May 2014
Business cards	Color printed cards with "Get the app, not the flu!" slogan, app logo, and website URL.	<ul style="list-style-type: none"> • Distributed at information tables, and during classroom and residence hall presentations • Student mailboxes 	Sept – Nov 2013
8' Free-standing banners	"Get the app, not the flu!" slogan with app logo and brief app description.	<ul style="list-style-type: none"> • Libraries • Academic buildings • Student health center 	Sept 2013 – May 2014
Information tables	Staffed by street team for app demonstrations and distribution of business cards, stickers, and candy during times of high campus traffic.	<ul style="list-style-type: none"> • Student Unions • Dining Halls 	Sept – Oct 2013
Presentations	Short 2-5 minute presentations describing the app, raffle, and study goals. Given with PowerPoint slides and distribution of business cards. Presentation delivered by <i>OutSmart Flu</i> team members, or a single slide presentation delivered by the professor using a script distributed via email.	<ul style="list-style-type: none"> • Student organizations • Residence hall meetings • Large, entry-level classes with instructor permission 	Sept – Dec 2013
Mass email	Study description and invitation to enroll by downloading the using the app. Email included a link to the study website.	<ul style="list-style-type: none"> • All undergraduate university-issued email addresses 	Feb 2013
Email invitations	Study information and instructions for enrollment sent for distribution to student listservs.	<ul style="list-style-type: none"> • Select student orgs • Residence life leaders • Heads of schools & academic departments • All math majors 	Oct 2013
Website	Containing FAQs, detailed study description, study information sheet, and study team profiles.	<ul style="list-style-type: none"> • Target population and other interested parties 	Sept 2013 – May 2014

Social media posts	Text and photo announcements circulated through Facebook and Twitter pages.	<ul style="list-style-type: none">• University affiliated accounts• Student groups and clubs	Sept 2013 – May 2014
University and local press	Announcement of app availability and project novelty.	<ul style="list-style-type: none">• UW website• Featured in UW weekly• Radio interviews• Student newspaper	Sept 2013 – Feb 2014

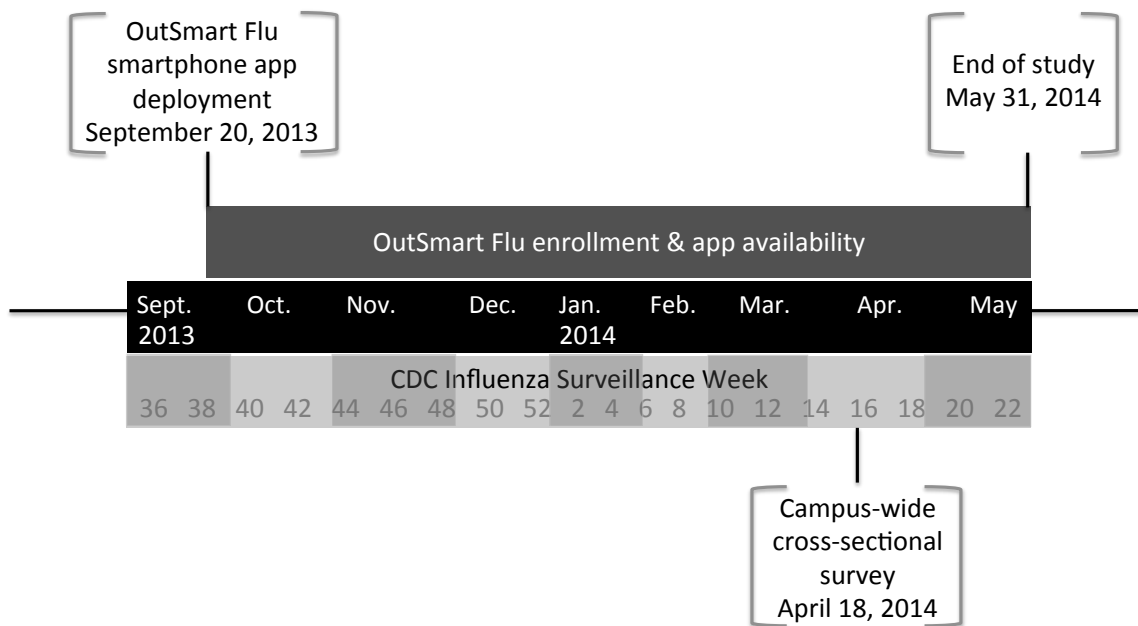


Figure 3. Timeline of *OutSmart Flu* Components by Calendar and CDC Week

Chapter 4: Influenza Vaccination Coverage among University Students

Introduction

Influenza and Vaccination in University Student Populations

Due to close interactions, influenza-like illnesses (ILI) are able to spread rapidly among university students, and cause significant morbidity resulting in absenteeism, impaired work and academic performance, increased health care use, and substantial decrease in general health (Nichol et al., 2005). Although occurrence of ILI varies widely between seasons within all populations, university students are at notably higher risk compared to other young adults. Studies have found the incidence of ILI among healthy adults to range between 2%-10% in non-pandemic years (Bridges et al., 2002; Eysenbach, 2006). In contrast, among university students, incidence of ILI has been found in excess of 25% (one study reported 36.7% incidence among university students during the 2002-03 influenza season) (Pons et al., 1980; Sobal and Loveland, 1982).

The Centers for Disease Control and Prevention (CDC) Advisory Committee on Immunization Practices (ACIP) recommends routine annual influenza vaccination for all persons aged six months or older, as the most effective influenza prevention tactic (Grohskopf et al., 2014). Two types of influenza vaccines are currently licensed for use, the first containing live attenuated influenza virus (LAIV) and the second containing inactivated influenza virus (IIV). Vaccine efficacy is variable across years dependent on a variety of factors including the match of circulating strains. The IIV vaccine has been

found to have 70-90% efficacy in a typical year (Monto et al., 2009; Nichol et al., 2008; Ohmit et al., 2006), and research has shown LAIV to perform with similar or lesser efficacy as compared to IIV in adults (Ambrose et al., 2011; Monto et al., 2009; Ohmit et al., 2006; Ohmit et al., 2008). Early widespread vaccination, implemented in conjunction with other influenza prevention behaviors, is key to effective interruption of influenza transmission (Suess et al., 2012).

Healthy People 2020's target goal for vaccination of adults aged eighteen to sixty-five is 80% for the annual influenza vaccine (U.S. Department of Health and Human Services, 2010). Influenza literature cites 80-90% coverage required to establish herd immunity (Plans-Rubió, 2012). Vaccination rates among university students continues to be low despite the heightened risk of influenza within this population (Ramsey and Marczinski, 2011(American College Health Association, 2012). The Healthy People target of 80% is a notable increase for university campuses where influenza vaccination rates were estimated to be 33.9% in a 2010 survey (American College Health Association, 2012). The target goal set by American College Health Association's (ACHA) Healthy Campus 2020 is a 10% increase in influenza vaccination rates on university campuses to reach 43.9% by 2020 (American College Health Association, 2012).

University-specific prevalence estimates of influenza vaccination are based on the number of vaccinations delivered to students through the student health center (SHC), and supplemented, when available, by self-reported vaccination status as reported in student medical histories (Sarah Van Orman MD, personal communication, October 31, 2014); the accuracy of these estimates is dependent on the unmeasured prevalence of off-campus vaccination. The purpose of this study is to characterize influenza vaccination

practices in a population of university students. This work examines the following measures: prevalence of the 2013-14 vaccine, location of vaccine receipt (on-campus vs. off-campus), and factors associated with or influencing the vaccination decision.

Methods

Study Design and Eligibility

Data used in these analyses were collected as part of the *OutSmart Flu Surveillance & Research Initiative* conducted at the University of Wisconsin-Madison during the 2013-14 academic year. The *OutSmart Flu* project was comprised of both interventional and observational components. An integral component of the project was the *OutSmart Flu* smartphone app, which was made available to all members of the university campus, and provided study participants with an interface to report real-time presence or absence of ILI symptoms, view updated ILI campus trends, access influenza prevention tips, and participate in influenza-related research surveys.

An online, cross-sectional, 61-item survey (Appendix B.1) was administered campus-wide via email during the Spring 2014 semester. This survey included questions regarding familiarity with the *OutSmart Flu* initiative; influenza knowledge and beliefs; influenza history and prevention practices; and demographics. The questionnaire was pre-tested on student volunteers for readability, and clarity of meaning and instructions. *Qualtrics* survey software (Qualtrics, Provo, UT) was used to develop, distribute, and administer the survey. Individuals having a university issued email address were eligible for inclusion if they reported undergraduate student status, and were seventeen years of age or older at the time of survey completion. Survey respondents were eligible

regardless of use of the *OutSmart Flu* app. Participants were offered an opportunity to enter a raffle to win one of eleven cash prizes ranging from \$25 to \$100 as incentive for participation.

Data

The survey question regarding vaccination location provided respondents with four response options: 1) University Health Services (i.e., SHC), 2) On-campus flu shot clinic, 3) Off-campus primary care provider, and 4) Other off-campus venue. For these analyses, responses were dichotomized into on-campus and off-campus venues.

Age was dichotomized as 25 years and younger versus 26 and above. Age is correlated with class standing; however, an age variable dichotomized at this threshold enabled the separation of traditional and non-traditional students, as well reflecting eligibility for health insurance coverage under parental/ guardian plans.

A hand washing priority variable was created from ten items presenting scenarios for which the respondent was asked to prioritize hand washing using a five-point scale (Appendix B.1). The priorities were assigned values 1-5 corresponding to priority level (1 being 'Not at all' and 5 being 'Essential') and summed across items to create a hand washing priority variable ranging from 0-50. Hand washing priority was expected to correlate with other preventative health behaviors (i.e. influenza vaccination).

Statistical Analysis

Demographic distributions of the study population were compared to the target population using χ^2 tests and enrollment data provided by the university registrar. To identify factors associated with 2013-14 vaccination status and vaccination location

among those vaccinated, χ^2 , Fisher's exact, and t-tests were used as appropriate.

Variables of conceptual importance and variables found to be associated with vaccination status in univariable analysis were included in adjusted logistic regressions. Bidirectional elimination was used to select variables for inclusion in the final models. Interaction terms were constructed based on theoretical expectations and tested for statistical significance.

To decrease the potential for differential response bias, post-stratification weights were applied to estimate campus-wide vaccination rates. Weights were calculated using the concurrent Undergraduate Enrollment By Diversity Report (Spring 2013-14) available from the registrar stratified by school of study, class standing, and sex. For students having undeclared or undecided majors, the stratifications by both class standing and sex were not included in the registrar's report. These weights were estimated using the separate proportions reported for each group. Weights based on class standing provided adjustment for a disproportionate number of respondents having freshman status. This weighting was used to improve generalizability of findings due to many freshmen living on campus and having increased exposure to vaccination campaigns occurring within residence halls. Weights based on school of study and sex served to decrease the potential for differential response bias resulting from higher vaccination rates among women (Deeks et al., 2009) and the potential for knowledge gained from scientific fields of study such as biology to impact the vaccination decision, leading to increased interest in vaccination studies and higher response rates as compared to men and non-science majors. To improve the validity of campus-level vaccination rates, an additional adjustment was applied to down-weight responses of vaccinated participants;

this response-rate weighting was done to compensate for the higher likelihood of vaccinated students responding to an influenza-prevention survey as compared to unvaccinated students, due to an unmeasured health interest or motivation. The following weight was calculated based on the response rate ratio by reported 2014 influenza vaccination status and was applied to vaccinated respondents:

$$\frac{P(\text{survey response} \mid \text{unvaccinated status})}{P(\text{survey response} \mid \text{vaccinated status})}$$

All analyses were conducted using STATA version 13.1 (StataCorp, College Station, TX).

Results

Cross-sectional Study Sample

Among the 27,833 undergraduate students enrolled for the Spring 2014 semester, 2,022 (7.0%) completed the survey and met eligibility criteria. An additional 1,134 survey responses were ineligible; main reasons for ineligibility were incomplete surveys and non-undergraduate status. The majority (N=1,710, 84.6%) of the study subjects were between 18 and 22 years of age with an additional 312 (15.4%) reporting ages ranging from 23 to 54 (IQR: 23-24). Seniors comprised the largest proportion (N=602, 29.8%) of the study sample, with juniors, sophomores, and freshmen constituting the remaining 23.5%, 22.5% and 24.2%, respectively. Participation for this study was relatively higher among students in specifically related areas of study: the largest proportion of study participants (N=800, 41.8%) were from the College of Letters and Science, followed by 507 (26.5%) from Agricultural and Life Sciences (CALS), and 247 (12.9%) from

Engineering. The remaining sample was comprised of students from the schools of Education (N=151, 7.9%), and Human Ecology (N=92, 4.8%). One hundred and eighteen (6.2%) participants reported undecided or undeclared majors. In this study we observed an association between sex and survey response, with female students comprising over two-thirds of the sample (N=1,390, 68.9%) and male students comprising less than one-third (N=622, 30.8%). Differences between the university demographics as reported by the registrar and those observed in the study sample were statistically significant across each available variable (Table 3).

2013-14 Vaccination

Of the undergraduate students surveyed, 1,205 (59.7%) reported vaccination during the 2013-14 influenza season. When asked about vaccination history, 410 (20.3%) students reported that they have no history of ever receiving the influenza vaccine. No measured demographic factors were found to be statistically associated with history of never having received the influenza vaccine. Application of the post-stratification weights resulted in an estimated 57.4% campus-wide vaccination rate, with an estimated 19.8% of students having no history of ever receiving influenza vaccination. Further adjustment incorporating the estimated survey response rate ratio by vaccination status resulted in an estimated 27.8% campus-wide vaccination rate.

Of the participants reporting 2013-14 vaccinations, 864 (72.0%) reported having received the seasonal vaccine in the past, and 341 (28.3%) indicated that this was the first time they had received the vaccine. Sex, class standing and housing were statistically associated with first-time vaccination (Table 4). Male students were found to be more likely to be first-time vaccinees as compared to female students, freshman students were

found to be more likely to be receiving the vaccine for the first time as compared to other students, and students living near campus in an apartment or house were most likely to report first-time receipt of that vaccine as compared with students reporting other housing arrangements. The weighted analysis produced an estimate of 65.2% of currently vaccinated students having received the vaccine in the past, and 43.0% receiving the vaccine for the first time in 2013-14. Univariable analysis showed an association between 2013-14 vaccination and students living on campus and those living with other students as roommates. History of previous vaccination was statistically associated with vaccination in the current year (Table 5). Consistent with other findings (Coe et al., 2012; Seale et al., 2010; Setbon and Raude, 2010; Maurer J, 2009; Lau JTF, 2010), factors strongly associated with likelihood of 2013-14 vaccination in this sample included prior receipt of influenza vaccination and intent to vaccinate during the 2014-15 influenza season (Table 6). The final model included vaccination history (prior receipt of influenza vaccine), intent to receive the 2014-15 vaccine, academic class standing, sex, school of study, health insurance coverage, and self-reported hand washing practices. No interactions were found to be significant in this model.

The majority of the vaccinated students reported receiving the vaccine through the SHC (N=967, 80.3%); of these, 747 (62.0%) had been vaccinated at the main University Health Services clinic and 220 (18.3%) at a satellite, on-campus flu-shot clinic. The vaccination coverage estimates extended to the campus-level using post-stratification weights produced similar estimates (Table 7). The factors individually associated with likelihood of on-campus 2013-14 vaccination in this sample were related to living arrangements, specifically: living in an on-campus residence hall, having student

roommates, and living with parents and/or family (Table 8). The final multivariable model included academic class standing, sex, school of study, health insurance coverage, having student roommates, living with parents and/or family, and being older than 26 years (Table 9). No interactions were found to be statistically significant in this model. Within this model, vaccinated students having their own health insurance plan were found to be 3.6 times more likely (95% confidence interval: [1.58, 8.04]) to have received the 2013-14 vaccine on campus as compared to vaccinated students listed as a dependent on their parent's or another adult's insurance plan. Students under age 26 were found to be 3.6 times more likely (95% confidence interval: [1.23, 10.29]) to receive on-campus vaccination as compared to vaccinated students 26 years of age and older.

Discussion

This study found 59.7% of surveyed students to have reported receipt of the influenza vaccine during the 2013-14 season. This work used a weighted analysis, adjusting for school of study, class standing, and sex, to estimate a campus-wide vaccination rate of 57.4% for the University of Wisconsin-Madison. Further adjustment to down-weight vaccinated participants according to the estimated survey response rate ratio by vaccination status resulted in an estimated vaccination rate campus-wide of 27.8%. Previously, campus vaccination rates have been estimated based on the number of vaccinations delivered to students through the SHC. Through the inclusion of students vaccinated off-campus, this study provides a more comprehensive estimate of vaccine coverage on campus, however, the weighted analyses evidence that self-selection bias is likely to have inflated the estimates above the actual campus vaccination rate. During this influenza season, the SHC estimated vaccination of 29.0% of the campus through

vaccines delivered at the SHC facility and flu shot clinics (Sarah Van Orman MD, personal communication, October 31, 2014), a statistic demonstrating over-adjustment by application of the response rate weights. Findings of this study indicate that nearly 20% of vaccinated students may receive off-campus vaccination; therefore, the previously used estimation is likely to underestimate the campus vaccination rate.

Actual campus vaccination rates are likely to lie in the range between the SHC estimation of 29.0%, and the survey estimation of 57.4% (which is likely subject to over-estimation due to self-selection bias). While the estimated campus-wide vaccination rate of 57.4% exceeds the target goal of 43.9% set by ACHA's Health Campus 2020, this level of vaccination should not be considered sufficient. The target set by ACHA was determined with the purpose of introducing a 10% improvement in the statistics reported by university students in 2010. The estimated vaccination rate achieved by the university, is better measured against the Healthy People 2020's target goal for 80% influenza vaccination coverage of adults aged 18 to 65, or against the 80-90% coverage required to establish herd immunity (Plans-Rubió, 2012).

To increase vaccination rates on university campuses, opportunities were examined for vaccine uptake in sub-populations of university students comparatively under-vaccinated. In this study, we found many unvaccinated students to be living in residence halls on campus and with other students as roommates. Of students surveyed, 40.4% reported unvaccinated status for the 2013-14 influenza season, and among unvaccinated students, 29.2% reported living in residence halls. This finding is particularly concerning from a public health perspective, because influenza has high transmissibility in residence halls due to close contact in shared spaces. Students living in residence halls present an

opportunity for targeted interventions with a potentially high return in interruption of viral transmission. Research findings based on the Health Belief Model (HBM) as a theoretical framework, have shown that low perception of susceptibility to be a significant barrier affecting uptake of preventative health behaviors such as influenza vaccination (Seale et al., 2010; Janz and Becker, 1984). Interventions directed towards unvaccinated students may become more effective by targeting risk perceptions to raise perceptions of susceptibility through explanations of influenza transmission and heightened risk due to frequent close exposure to other students. The findings of this study show that students living in residence halls are most likely to be vaccinated on campus; this provides support for initiatives such as mobile flu shot clinics making the vaccines readily available to this subgroup comprising nearly one third of unvaccinated students.

Among undergraduate students, freshmen are most likely to live in residence halls on campus. Residence halls pose an elevated risk for influenza transmission; therefore, higher vaccination rates among freshmen are optimal in the control of influenza on campus. However, this study did not find freshmen to be more likely to be vaccinated when compared to any other class standing. Vaccination campaigns targeted towards freshmen may present a valuable opportunity for improvement in vaccine coverage. An estimated 43.0% of students vaccinated in 2013-14 were first-time vaccinees; this statistic shows promise for behavioral change. Vaccination campaigns targeting freshmen would be opportune, not only to increase coverage within residence halls, but also to target a demographic reaching a transition point in their health practices. The findings of this study are consistent with literature showing history of influenza vaccination to be an

exceptionally strong predictor of future vaccination (Bödeker et al., 2014; Naleway et al., 2014). Encouraging freshman to adopt vaccination as part of their annual preventative health practices, introduces the potential to impact campus-wide vaccination rates for an average of three additional years as university students.

Consistent with other studies in the literature (Deeks et al., 2009), this research has shown males to be a comparatively under-vaccinated subgroup. In this population, women were 1.7 times more likely to have received the 2013-14 vaccine as compared to men. The HBM may provide a helpful framework for future studies examining differences between males and females in factors associated with vaccination decision-making. However, it is important to note, that while opportunity exists for improvement of vaccine uptake in the previously mentioned sub-populations, overall vaccination rates remain suboptimal in this population, such that increased uptake among women and other groups with comparatively higher vaccine prevalence will also provide significant opportunity to approach vaccination rates effective for interruption of influenza transmission on university campuses.

Limitations and Potential Biases

A limitation of this study was the potential bias introduced by use of a convenience sample for recruitment. It is likely that students self-selecting to participate in this survey are also more likely to engage in influenza prevention practices and hold opinions of the influenza vaccine that differ from those of non-respondents. Students with strong anti-vaccine attitudes may be less likely to respond to a survey about influenza vaccines, causing differential non-response, which would lead to an overestimation of campus vaccination rates and threaten the study validity. While post-stratification

weights were used to adjust for several important demographics, any unmeasured factors, relating to both response and vaccination, remain unadjusted such that residual confounding may be present resulting in biased estimates.

Previous studies have shown that non-Caucasian racial groups have been more accepting of pandemic influenza vaccines (Seale et al., 2010). A limitation to this research is the absence of a race measure in this survey, preventing adjustment for race within our vaccination models, and also preventing adjustments toward from being made for under sampling of any racial group. Should influenza vaccination practices among university students vary between racial groups, this unmeasured factor may lead to threats for generalizability.

Conclusion

Use of post-stratification weights to analyze influenza vaccination survey data produced an estimate of campus-wide vaccination, which included students vaccinated off-campus, and increased the estimate from the previously used method by more than 20%. Due to self-selection of participants, the weighted analysis is likely to have overestimated true vaccination rates; even so, this increased estimate lies well below the optimal level for influenza vaccination within this high-risk sub-population of young adults. These findings provide additional support for public health interventions to raise vaccination rates within this population. Freshmen, specifically, are a key group to target for influenza vaccinations; establishing a history of vaccine receipt within this group will continue to impact their vaccination decisions throughout their tenure as members of the university campus. Targeting perceived susceptibility, as well as other HBM components, through continued education of influenza transmission and prevention is recommended

and may positively impact vaccine-uptake on college campuses, resulting in lessened absenteeism, impaired work-performance, and healthcare utilization due to influenza transmission among university students.

Table 3. Comparison of Demographic Information for University Population and Study Population (N= 2,022)

Demographic	University population		Study population		p value χ^2 test
	%		%	N	
Sex					<0.001
Male	48.5		30.8	622	
Female	51.5		68.9	1390	
Prefer not to answer	-		0.3	6	
Class standing					<0.001
Freshman	8.34		24.2	489	
Sophomore	22.0		22.5	455	
Junior	27.1		23.5	476	
Senior	42.6		29.8	602	
School of study					<0.001
Ag & Life Sciences	12.5		26.5	507	
Education	6.3		78.0	151	
Engineering	14.8		12.9	247	
Human Ecology	3.4		4.8	92	
Letters & Science	53.6		41.8	800	
Undecided/ undeclared	29.6		6.16	118	
Age					<0.001
<=18	14.7		0.2	3	
19	22.6		15.1	306	
20	22.2		23.1	467	
21	21.7		23.4	474	
22	11.0		22.8	460	
23	3.0		9.1	183	
>=24	4.8		6.4	129	

Accessed: (5.30.2014) http://registrar.wisc.edu/documents/Stats_all_2013-2014Spring.pdf. Students with more than one major are counted by the registrar proportionally in each major so that the number of majors equals the total number of students. The survey conducted in this research only allowed for respondents to report one major.

Table 4. Demographics Associated with First-time Vaccination

Demographic	First-time vaccination (N=341) N (%)	Previous vaccination (N=864) N (%)	p value χ^2 test
Sex			0.001
Male	124 (36.5)	234 (26.9)	
Female	216 (63.5)	637 (73.1)	
Class standing			<0.001
Freshman	148 (43.4)	165 (18.9)	
Sophomore	67 (19.7)	197 (22.6)	
Junior	52 (15.3)	230 (26.4)	
Senior	74 (21.7)	279 (32.03)	
Housing			<0.001
On-campus res hall	240 (27.6)	168 (49.4)	
Near-campus apt/house	558 (64.2)	139 (40.9)	
Off-campus/commuter	54 (6.2)	28 (8.2)	
Frat/Sorority house	15 (1.7)	4 (1.2)	
Other	2 (0.2)	1 (0.3)	

Table 5. Characterization of Study Population by 2013-14 Vaccination Status

Variable	Vaccinated 2013-14 (N=1,205) N (%)	Unvaccinated 2013-14 (N=817) N (%)	p value χ^2 test	Weighted % Vaccinated 2013-14	Weighted % Unvaccinated 2013-14	p value χ^2 test
Freshman	313 (26.0)	176 (26.0)	0.149	14.9	13.1	0.736
Sophomore	260 (21.6)	194 (23.9)		28.0	28.8	
Junior	282 (23.4)	194 (23.9)		27.6	25.7	
Senior	350 (29.1)	249 (30.6)		29.6	32.5	
Male	356 (29.6)	269 (33.2)	0.194 (F)	48.6	47.6	0.809
Female	848 (70.4)	542 (66.8)		51.4	52.4	
Unreported	1 (0.1)	2 (0.3)				
On-campus residence hall	407 (33.9)	238 (29.2)	0.022 (F)	23.5	26.1	0.1943
Near- campus apt/house	692 (57.6)	475 (58.7)		66.9	62.3	
Off-campus/ commuter	81 (6.7)	79 (9.7)		6.3	9.8	
Fraternity/ Sorority house	19 (1.6)	14 (1.7)		1.9	1.2	
Other	3 (0.3)	6 (0.7)		1.5	0.7	
Student roommates	1,030 (85.8)	659 (81.6)	0.012	81.0	78.3	0.4
Non-student roommates	53 (4.4)	52 (6.4)	0.046	4.9	6.8	0.194
Parents/ family	48 (4.0)	35 (4.3)	0.711	4.9	4.8	0.998
Other	10 (0.8)	19 (2.4)	0.005	0.4	1.9	<0.001
Living alone	111 (9.2)	76 (9.4)	0.901	13.8	12.2	0.599
Agricultural & Life Sciences	291 (26.2)	215 (26.5)	0.934	10.5	10.5	0.441
Education	92 (7.6)	59 (7.3)		5.2	5.3	
Engineering	140 (11.6)	106 (13.0)		10.4	14.7	
Human Ecology	52(4.3)	40 (4.9)		2.6	3.2	
Letters & Science	471 (39.1)	327 (40.2)		46.1	42.7	
Undecided	66 (5.5)	52 (6.4)		25.2	23.8	
Not Reported	93 (7.7)	14 (1.7)				
Insured	1,149 (95.4)	765 (94.1)	0.166	93.8	93.0	0.747

Uninsured	38 (3.2)	39 (4.8)		5.3	6.4	
Unsure	15 (1.2)	9 (1.1)		0.9	0.7	
Own insurance plan	105 (8.7)	96 (11.8)	0.008	11.8	11.0	0.952
Other insurance plan	1,039 (86.2)	659 (81.1)		81.8	82.4	
Unsure	51 (4.2)	50 (6.2)		6.4	6.6	
Vaccinated 2012-13			<0.001			<0.001
Yes	815 (67.6)	201 (24.7)		70.4	28.4	
No	390 (32.4)	612 (75.3)		29.6	71.6	
Influenza vaccine (prior to 2012-13)			<0.001			<0.001
Yes	721 (59.8)	309 (38.0)		59.7	40.2	
No	484 (40.2)	504 (62.0)		40.3	59.8	
Never vaccinated	0 (0.0)	410 (50.6)	<0.001	0.0	46.5	<0.001
Intend to receive vaccine (2014-15)			<0.001			<0.001
Yes	1,096 (91.2)	164 (20.2)		91.3	24.1	
No	23 (1.9)	442 (54.4)		1.3	51.2	
Not sure	83 (6.9)	207 (25.5)		7.5	24.8	
Hand-washing scale (0-40)	26 (21-30)	25 (20-30)	<0.001			

(F) Denotes use of Fisher's exact test in place of χ^2 test.

Table 6. Demographic Factors Associated with Receipt of the 2013-24 Seasonal Influenza Vaccine in Multivariable Logistic Model

Item	OR [95% CI]	p value
Never vaccinated (reference)	-	-
Received prior vaccination (not in 2012-13)	3.748 [2.231 - 6.295]	<0.001
Received vaccination both prior to, and during 2012-13 season	10.880 [6.896 - 17.165]	<0.001
Intention to receive 2014-15 vaccine	49.238 [21.405 - 113.265]	<0.001
Senior (reference)	-	-
Junior	0.767 [0.481 - 1.222]	0.264
Sophomore	0.814 [0.488 - 1.360]	0.433
Freshman	0.970 [0.441 - 2.133]	0.940
Male (baseline)	-	-
Female	1.710 [1.153 - 2.536]	0.008
Letters & Science (reference)	-	-
Agriculture and Life Sciences	1.046 [0.666 - 1.645]	0.844
Engineering	1.031 [0.584 - 1.822]	0.916
Human Ecology	0.853 [0.381 - 1.913]	0.700
Education	0.724 [0.390 - 1.345]	0.307
Undecided/ Undeclared	0.412 [0.196 - 0.867]	0.019
Near-campus apartment/ house (reference)	-	-
On-campus residence hall	1.011 [0.545 - 1.877]	0.972
Off-campus/ commuter	0.838 [0.407 - 1.729]	0.633
Fraternity/ Sorority house	0.387 [0.136 - 1.106]	0.076
Other housing	0.157 [0.018 - 1.374]	0.094
On someone else's health insurance plan (reference)	-	-
Own health insurance plan	0.513 [0.291 - 0.905]	0.021
Self-reported hand washing practice scale	0.983 [0.957 - 1.010]	0.217

Table 7. Location of Vaccination among Vaccinated Students (N=1,205)

Vaccination Venue	Unweighted N (%)	Weighted %
University Health Services	747 (62.0)	59.4
On-campus flu shot clinic	220 (18.3)	20.3
Off-campus Primary Care Provider	131 (10.9)	10.5
Other off-campus venue	107 (8.9)	9.8

Table 8. Characterization of Vaccinated Students by Vaccination Location

Variable	On-campus vaccination (N=967) N (%)	Off-campus vaccination (N=238) N (%)	p value χ^2 test	Weighted % on-campus vaccination	Weighted % off-campus vaccination	p value χ^2 test
Freshman	264 (27.3)	49 (20.6)	0.054	15.4	9.1	0.072
Sophomore	214 (22.1)	46 (19.3)		30.0	21.8	
Junior	221 (22.9)	61 (25.6)		25.1	33.3	
Senior	268 (27.7)	82 (23.4)		29.5	35.8	
Male	293 (30.3)	63 (26.5)	0.242	50.5	39.0	0.043
Female	673 (69.6)	175 (73.5)		49.5	61.0	
Unreported	1 (0.1)	0 (0.0)				
On-campus residence hall	345 (35.8)	62 (26.2)	<0.001 (F)	25.4	13.4	<0.001
Near-campus apt/house	553 (57.3)	139 (58.7)		65.3	75.6	
Off-campus/ commuter	49 (5.1)	32 (13.5)		5.6	9.8	
Fraternity/ Sorority house	16 (1.7)	3 (1.3)		2.3	0.9	
Other	2 (0.2)	1 (0.4)		1.5	0.2	
Student roommates	848 (88.0)	182 (76.8)	<0.001	81.8	81.9	0.002
Non-student roommates	39 (4.1)	14 (5.9)	0.211	5.2	7.5	0.335
Parents/ family	24 (2.5)	24 (10.1)	<0.001	4.0	7.7	0.150
Other	6 (62.0)	4 (1.7)	0.106	0.3	0.8	0.200
Living alone	82 (8.5)	29 (12.2)	0.076	14.3	9.7	0.161
Agricultural & Life Sciences	226 (25.3)	65 (29.8)	0.197	10.3	11.4	0.759
Education	68 (7.6)	24 (11.0)		5.0	6.0	
Engineering	117 (13.1)	23 (10.6)		12.1	12.5	
Human Ecology	42 (4.7)	10 (4.6)		2.9	2.5	
Letters & Science	383 (42.8)	88 (40.4)		45.8	40.1	
Undecided	58 (6.5)	8 (3.7)		23.9	27.5	
Insured	921 (95.5)	228 (95.8)	0.660	93.0	96.1	0.324
Uninsured	32 (3.3)	6 (2.5)		6.1	3.1	
Unsure	11 (1.1)	4 (1.7)		0.9	0.9	
Own insurance plan	87 (9.1)	18 (7.6)	0.555	11.6	10.9	0.974
Other insurance	828 (86.4)	211 (89.0)		82.1	82.1	

plan

Unsure	43 (4.5)	8 (3.4)	6.3	7.0
--------	----------	---------	-----	-----

(F) Denotes use of Fisher's exact test in place of χ^2 test.

Table 9. Demographic Factors Associated with Location of 2013-14 Vaccine Receipt in Multivariable Logistic Model

Item	OR [95% CI]	p value
Senior (reference)	-	-
Junior	1.028 [0.674 - 1.568]	0.896
Sophomore	1.034 [0.652 - 1.637]	0.888
Freshman	0.680 [0.323 - 1.430]	0.309
Male (reference)	-	-
Female	0.914 [0.641 - 1.304]	0.620
Letters & Science (reference)	-	-
Agriculture and Life Sciences	0.758 [0.520 - 1.104]	0.149
Engineering	0.956 [0.552 - 1.653]	0.871
Human Ecology	0.907 [0.434 - 1.896]	0.795
Education	0.687 [0.397 - 1.186]	0.178
Undecided/ Undeclared	1.459 [0.641 - 3.324]	0.368
Near-campus apartment/ house (reference)	-	-
On-campus residence hall	0.564 [0.300 - 1.060]	0.075
Off-campus/ commuter	0.476 [0.190 - 1.194]	0.114
Fraternity/ Sorority house	0.729 [0.187 - 2.850]	0.650
Other housing	2.141 [0.121 - 38.037]	0.604
Student roommates	1.787 [1.087 - 2.935]	0.022
Parents and/or family roommates	0.376 [0.150 - 0.941]	0.037
On someone else's health insurance plan (reference)	-	-
Own health insurance plan	3.566 [1.583 - 8.037]	0.002
Under 26 years of age	3.555 [1.228 - 10.292]	0.019

Chapter 5: Determinants of Influenza Vaccination in a University Campus Population: A Health Belief Model Approach

Introduction

Seasonal Influenza and Vaccination

Epidemics of seasonal influenza are serious cause for public health concern both in terms of individual symptom severity and in breadth of population impact. Each year in the United States, influenza and influenza-like illnesses (ILI) are associated with increased burden on healthcare systems, lost work time and decreased productivity; in some cases, complications of the infection may lead to fatalities (CDC, 2011; Klepser, 2014). It has been estimated that 30% of acute respiratory infections in young adults are caused by influenza (Carrat et al., 1999; Nichol et al., 2005). Among university students, influenza has the potential to spread rapidly due to shared living and learning spaces on the university campus, resulting in significant effects on academic performance, absences from work and class, as well as increased antibiotic use and burden on university student health centers (Uddin et al., 2010; Nichol et al., 2005).

The Centers for Disease Control and Prevention (CDC) Advisory Committee on Immunization Practices (ACIP) recommends routine annual influenza vaccination for all persons aged six months or older as the most effective influenza prevention tactic (Grohskopf et al., 2014). Early widespread vaccination, implemented along with other influenza prevention behaviors, is key to effective interruption of influenza transmission

(Suess et al., 2012). Healthy People 2020's target goal for vaccination of adults aged eighteen to sixty-five is 80% for the annual influenza vaccine (U.S. Department of Health and Human Services, 2010). Vaccination rates among university students continue to be low despite the heightened risk of influenza within this population (Ramsey and Marczinski, 2011; American College Health Association, 2012). The Healthy People target of 80% is a notable increase for university campuses where influenza vaccination rates were estimated to be 33.9% in a 2010 survey (American College Health Association, 2012).

Health Belief Model

The status of influenza as a vaccine-preventable disease (U.S. Department of Health and Human Services, 2010) prescribes employment of (preventative) health behavior theory in the study of actions and attitudes surrounding individual influenza prevention practices. Kasl and Cobb have defined a health behavior as “any activity undertaken by a person who believes himself to be healthy for the purpose of preventing disease or detecting disease in an asymptomatic stage” (Kasl and Cobb, 1966). This class of behavior is contrasted with activities undertaken for the purpose of health improvement by those believing themselves to be ill.

The Health Belief Model (HBM) was developed for the purpose of conceptualizing health behavior (Rosenstock, 1974) and is a popular framework for studies addressing influenza vaccination uptake. The major components of the HBM are perceived susceptibility and severity (perceived threat when combined), perceived benefits and barriers, and cues to action; the association between each component and the behavior of interest is affected by modifying factors such as sociodemographics and knowledge about

the disease (Rosenstock, 1974).

In the context of influenza vaccination, *perceived threat* is defined as a function of an individual's perception of influenza severity and the individual's perceived susceptibility to influenza. A person who perceives influenza to be a severe disease, with serious consequences for health and function, will be more likely to engage in prevention practices such as vaccination, provided perceived susceptibility to influenza is sufficiently high as to induce a perception of threat. In the same manner, individuals perceiving themselves at risk for influenza infection will be more likely to seek vaccination due to perceived susceptibility, provided severity of influenza is also perceived. *Perceived benefits and barriers* capture an individual's perception of vaccine efficacy for influenza prevention, minus the individual's assessment of cost associated with vaccination. An individual perceiving that the benefits of vaccination, as an effective means of decreasing influenza risk, outweigh the perceived cost (e.g. side-effects, needle-phobia, inconvenience, etc.) will be more likely to comply with vaccine recommendations. *Cues to action* may come from physician recommendations, the media, observation of an ILI, or other stimulus serving as a catalyst for action to seek vaccination.

Conceptual Model for Influenza Vaccination

The sole focus of the HBM on perceptual and circumstantial factors has gained some criticism (Fishbein and Ajzen, 1972; Montano, 1986), asserting that the model is “more concerned with the subjective state of the individual than with history or experience” (Davidhizar, 1983). This charge may be warranted in the case of influenza vaccination compliance, as prior vaccination history has been found to be strongly associated with

future vaccination (Bödeker et al., 2014; Naleway et al., 2014). Regardless of these critiques, elements of the HBM have been shown to correlate with influenza vaccination compliance (Green, 2000; Larson et al., 1982); however, the relationship between these components is described only vaguely in the HBM. Therefore, this research proposes a modified HBM (incorporating history and experience) as the conceptual model forming the theoretical foundation to investigate the possibility for interactions at play in the vaccination pathway (Figure 4). This study aims to identify the relative importance of specific benefits and barriers to vaccination as perceived by vaccinated and unvaccinated subpopulations, and to capture and characterize cues to action influential in the vaccination decision.

Methods

Study Design and Eligibility

Data used in these analyses were collected as part of the *OutSmart Flu Surveillance & Research Initiative* conducted at the University of Wisconsin-Madison during the 2013-14 academic year. The *OutSmart Flu* project was comprised of both interventional and observational components. The *OutSmart Flu* smartphone app was an integral component of the project, which was made available to all members of the campus community, and provided study participants with an interface to report real-time presence or absence of ILI symptoms, view updated ILI campus trends, access influenza prevention tips, and participate in influenza-related research surveys.

The *OutSmart Flu* smartphone app and associated surveys were made available to all campus members having a university issued email address. Undergraduate students were

targeted for recruitment due to their higher use of the university's student health center (SHC) and heightened risk of influenza infection due to close interactions in residence halls and other shared spaces. Students in residence halls and large, entry-level classes were targeted for recruitment on the basis of convenience. To be eligible for inclusion in the *OutSmart Flu* research study, individuals were required to have completed successful account set up using a university issued email address login, including verification of receipt of the study information sheet, and were required to be age seventeen or above. Enrollment was rolling throughout the 37-week study period from September 20, 2013 to May 31, 2014, and eligible individuals were able to join the study at any time.

app-administered Survey Instruments

User Profile

The user profile allowed participants to report demographic characteristics and was available for completion or editing at any time during the study period following participant enrollment. The user profile contained a field for sex, major, date of birth, and housing arrangements (including options for specific residence halls).

Baseline Research Survey

A seven-minute research survey was made available for completion on the app immediately following account setup to collect baseline measurements. The survey contained 29 questions grouped into the following sections: 1) sociodemographic characteristics; 2) current usage of Smartphones for general and health-related purposes; 3) knowledge and attitudes toward influenza and prevention; and 4) influenza-related health history and behavior. Section 4 of this survey asked participants to report current vaccination status.

This study aimed to isolate influential benefits to vaccination among the subgroup of vaccination participants, and conversely, to examine significant barriers to vaccination among the subgroup of unvaccinated participants. The survey used skip patterns to direct participants reporting vaccination to respond to items designed to measure perceived benefits of vaccination, and in like manner, participants reporting not having received the vaccine were directed to respond to items designed to measure perceived barriers to vaccination (Appendix A.2). The baseline survey was set to remain available on the app until completion or study end date.

Follow-up Research Survey

As follow-up to the baseline survey, a second research survey was deployed in March 2014 during week 10 of CDC surveillance. This five-minute survey was made available to all users enrolled at the time of survey deployment, could be completed only once per account, and was set to remain available on the app until completion or study end date. The follow-up survey consisted of 32 questions, which measured demographics, re-measured sections 3 and 4 (knowledge and attitudes toward influenza and prevention, and influenza-related health history and behavior, respectively) from the baseline survey, and also included questions about the user's experience with and opinions of the app. The follow-up survey asked participants to report vaccination status for the 2013-14 influenza season. In parallel with the baseline survey, skip patterns were used to direct participants reporting vaccination to respond to items designed to measure perceived benefits of vaccination, and similarly, participants reporting not having received the vaccine were directed to respond to items designed to measure perceived barriers to vaccination (Appendix A.3).

Flu Prevention Survey

Users were asked twice a month to report flu prevention practices (including receipt of the vaccine) during the preceding two-week period. This survey was deployed on the 15th and 30th of each month (exception: February 28th), and remained open until the next deployment (Appendix A.5). To capture cues to action influencing the vaccination decision, this survey presented the following open-ended question to participants reporting receipt of the vaccine in the past two weeks: “What happened in the past two weeks to prompt you to get the 2013-14 vaccine?” Once completed, this survey was removed from the participant’s survey queue and remained unavailable until the next deployment date. Average completion time for this survey was less than one minute.

Statistical Analysis

Demographic distributions were calculated for the study population; baseline and follow-up survey populations were compared using χ^2 or Fisher’s Exact tests where appropriate. Overall demographics were compared between the study population and the university population using data available through the registrar. Items measured in the baseline survey were grouped according to corresponding HBM domains and Cronbach’s alpha was calculated for each measured domain. Multivariable logistic models were constructed to test significance of associations between baseline-assessed HBM domains and the vaccination decision ultimately reported at follow-up or through the flu prevention surveys. To avoid collinearity, one item was selected per domain for model inclusion. Inclusion of predictors was determined by Cronbach’s alpha (considering change in Cronbach’s alpha coefficient with the removal of each item in turn from the overall domain score). Scale items were dichotomized to improve interpretability. Items

were dichotomized from a five-scale response (e.g., strongly agree – strongly disagree, very likely – very unlikely, etc.) to an indicator variable; ‘neutral’ and ‘undecided’ levels of the scale were coded as zero with other non-positive, non-agreement scale levels. Final model covariates were selected based on conceptual significance (factors considered to be more upstream in the decision-making process were given precedence) and findings suggestive of statistical significance in univariable regressions (p value <.25). Conceptualized interactions between HBM domains and measured demographics were tested in the model for statistical significance.

Among participants reporting vaccination (at either baseline or follow-up), benefits reported as influential in the vaccination decision were summarized. Likewise, barriers reported as influential in the decision against vaccination were summarized among those participants reporting not having received vaccination at follow-up. Cues to action data from the flu prevention survey were categorized according to theme and summarized by frequency. Sub-analysis of barrier and cues to action data were completed for participants initially indicating (at baseline) “unsure” or “no” in response to vaccination intent, and ultimately reporting vaccination via the follow-up or flu prevention surveys. All analyses were conducted using Stata version 13.1 (StataCorp, College Station, TX).

Results

Among *OutSmart Flu* app users, 787 met the participant eligibility criteria (twelve additional users registered with invalid credentials and were excluded from analyses). The total study population was comprised of 281 (35.7%) males, 490 (62.3%) females, and 16 (2.0%) individuals of unreported sex. The demographic distributions of undergraduates within the sample population were found to differ with statistical

significance from the distributions at the university level (Table 10). Freshman and female students were found to be more likely to participate as compared to their peers.

The baseline survey was completed by 589 (74.8%), the follow-up survey was completed by 188 (23.9%), and 461 (58.6%) of participants responded to at least one flu prevention survey (Figure 5). Of the 389 participants ultimately reporting vaccination, 325 (83.5%) completed one or more flu prevention surveys. The distribution of participants did not change significantly according to sex, age, school of study, university affiliation, housing, or living companions between the baseline surveys delivered at enrollment and the follow-up survey. The proportion of participants ultimately reporting 2013-14 vaccination (via baseline, follow-up, or prevention survey) was greater (78.7%) among follow-up survey participants as compared to the participants at baseline (63.3%) (Table 11).

Internal consistency of survey items intended to measure HBM domains was acceptable ($0.6 \leq \alpha < 0.7$) as assessed by Cronbach's alpha scores (APPENDIX C.1). The final multivariable model included sex, undergraduate status, perceived severity ('If I were to get the flu, my symptoms would be serious,' dichotomized scale), perceived susceptibility ('I am at risk of getting the flu,' dichotomized scale), perceived benefits of vaccination ('The seasonal vaccine will protect me from the flu,' dichotomized scale), perceived barriers to vaccination ('There are reasons why I cannot get the flu vaccine,' dichotomized scale), and influenza and vaccination history ('Have you ever received the seasonal flu vaccine?' and 'Do you believe you have ever had the flu?') (Table 12). Interactions were tested between sex and each of the covariates, between undergraduate status and each of the covariates, and between perceived severity and perceived

susceptibility. No interactions were found to be statistically significant in this model. Participants who reported undergraduate status were 4.5 times less likely to ultimately report vaccination as compared to participants reporting graduate, faculty, or staff status or other university affiliation. History of past influenza vaccination showed the strongest association with vaccination in the observed influenza season; participants previously vaccinated were 8.2 times more likely to ultimately report vaccination as compared to participants never having received the vaccine or unsure of vaccination history.

Among respondents reporting receipt of vaccine, influential perceived benefits were assessed. Benefits were reported at the time vaccination was reported (either in the baseline or follow-up survey) (Table 13). Most commonly reported as having any influence (92.0%) on the vaccination decision was vaccine effectiveness to ‘decrease likelihood of getting the flu;’ this benefit was also the most likely to be reported as having ‘strong influence’ (69.1%) on the decision. Ease and convenience of vaccination was also frequently reported (91.1%) as influential in the vaccination decision, with 56% reporting ‘strong influence’ of this factor on the vaccination decision. Similarly, barriers were assessed among those reporting having not received the vaccine at follow-up. Preference for alternate protection techniques was most frequently reported as having any influence on the decision. However, needle phobia was most frequently reported as having ‘strong influence’ on the decision.

The flu prevention survey was completed a total of 1,834 times with responses from 461 unique individuals. Of these responses, 167 included report of vaccination receipt and 129 (77.2%) of these vaccination reports included a cue to action. The most frequent themes reported in these cues included requirement for work/school/volunteer position

(14.4%), convenience of location and time (13.8%), a seasonal cue with approach of flu season (17.4), and finding sufficient time (11.4%) (Table 14).

Sub-analysis of participants with intention change (i.e., unvaccinated at baseline and having reported ‘no’ or ‘unsure’ in response to being asked if they intend to receive the seasonal vaccine, and later reporting vaccination in the follow-up or flu prevention surveys) identified 18 (4.2%) participants. Due to small sample size, response distributions were not compared to the general participant population; however, inconvenience and concern for potential side effects were frequently reported as influential within this subgroup (Table 14). Cues to action reported within this subgroup included prompts from family, others becoming ill, and convenience (Table 16).

Discussion

This study utilized a smartphone app to investigate effects of HBM domains on the vaccination decision in a university setting, identify specific influential benefits and barriers as perceived by participants, and capture cues to action among the subset of vaccinated app users. Survey items were constructed based on HBM domains, and cues to action were collected in open-ended question format.

This research specifically examines perceived benefits and barriers, as well as cues to action for vaccination within a university population. Due to the proximal relationship of perceived benefits and barriers to the vaccination decision, as described by the HBM, this component holds added importance from a public health perspective. A sufficiently substantial barrier may prevent the outcome even in the case that upstream factors such as perception of susceptibility and severity are prime to encourage

vaccination. The findings of this study are easily translated to practice as public health interventions seek to target under-vaccinated sub populations, increase understanding of vaccination benefits, and remove barriers to vaccination.

This research found vaccination history and undergraduate status to be the strongest predictors of vaccination decision in this population. Among the HBM components, perceived severity, perceived benefits and perceived barriers were strongly associated with the vaccination decision, however, these associations were not found to be statistically significant in this study. Among perceived benefits reported at the time of vaccination report (either in the baseline or follow-up survey), vaccine effectiveness and ease and convenience of vaccination were most frequently reported as being influential in the decision process. These findings provide support for continued education of vaccine effectiveness and laud public health efforts creating ease and convenience of vaccination – suggesting that these factors are perceived as benefits to vaccination and are valued highly by individuals within university settings.

Among perceived barriers measured at follow-up among those reporting having not received the vaccine, preference for alternate protection techniques was most frequently reported as having any influence on the decision. This finding suggests that perceived benefits of vaccination may be low in comparison to perceived barriers resulting in adoptions of alternate measures to protect against influenza threat. Education of this subpopulation regarding superiority of vaccine effectiveness among flu protection measures may lead to a more holistic approach to flu prevention, encouraging incorporation of methods such as sufficient sleep, healthy diet and hand hygiene, *in addition* to vaccination. Further, vaccine effectiveness education may also impact

additional barriers identified in this research including concern for potential side effects, and doubt of vaccine effectiveness. The barrier most frequently reported as having ‘strong influence’ on the vaccination decision was needle phobia. Although prevalence is difficult to assess, needle phobia has been estimated to affect up to 21% of the population, causing mild to intense fear (and in some situations, severe phobic reactions) and resulting in avoidance of medical systems and treatments. (Hamilton, 1995; Jenkins, 2014). Needle phobia can be managed via reassurance and education (Hamilton, 1995); discussions of prevalence and normality of needle fear legitimizes patient concerns and may lead to decrease in embarrassment and fear of needle encounters.

A limitation of this research was the survey design resulting in measurement of perceptions of influential benefits only among respondents reporting vaccination, while perceptions of influential barriers were measured only among respondents not reporting vaccination. This design prevents associations between perceptions of benefits and barriers and vaccination occurrence from being assessed. Future studies are needed to identify the impact of perceived barriers within vaccinated subpopulations, and the influence of perceived benefits within unvaccinated subpopulations. A barrier not assessed in this study was cost of vaccination. Within this specific population, vaccines may be obtained free of charge from the SHC, however, cost may present a substantial barrier in other university populations. Within this study, cues to action data indicate that vaccinees value availability of free vaccines, and view this lack of barrier as a cue to vaccination.

Cues to action research is difficult to conduct because the cues must be salient at the time of measurement. Such cues are difficult to assess if the instrument for data

collection is not available to the participant at the time the decision is made. The use of smartphones allows the capture of cues to action within the vaccination pathway. This research sought to characterize effective cues to vaccination within this population. Frequently reported cues to action included vaccination requirements for school/work/volunteer positions, convenience of vaccination location and time, seasonal cues (i.e. approaching flu season), and finding sufficient time to follow through on intention. These findings support mobile vaccination clinics located strategically on campus to maximize convenience of, and minimize time invested in vaccination. Prevalence of these cues may also support messaging announcing approach of the flu season, and emphasizing ease and minimal time investment associated with vaccination.

While the smartphone approach provides participants opportunity to immediately record salient cues to action at the time of vaccination, the flu prevention survey responses may have been submitted with up to two-weeks lag since vaccination. This type of delay may be responsible for decreased response rate within the cues to action question, as well as failure to capture more fleeting cues. Future study designs may improve on timeliness of cues reporting, however, additional prompts for frequent app interaction may create annoyance among users and result in increased losses to follow-up. Additionally, the response rate of 58.6% to the flu prevention survey introduces opportunity for non-response to bias the themes reported in the cues to action data. Findings of this study must be interpreted cautiously when making generalizations.

Among participants experiencing intention change, inconvenience and concern for potential side effects were frequently reported as influential in the decision against vaccination. Due to small sample size within this subgroup, this study was not able to

compare frequency of barriers overcome in the context of intention change to barriers not overcome among those reporting not having received the vaccine at follow-up. Further research is needed to more conclusively identify barriers to vaccination overcome and cues to action experienced by persons initially without intent to receive the vaccine and later reporting vaccination. In the consideration of overcoming barriers, it is interesting to note the distributions of influence reported for each barrier examined in this study – barriers need not be conceptualized as dichotomous entities. Future research investigating existence of barrier thresholds and identifying barriers frequently overcome will be important to identify areas for public health efforts to decrease vaccination barriers to yield highest returns. Concurrent cues to action research may provide clues indicating the means by which barriers can be overcome.

This study presents interesting and useful findings regarding benefits, barriers, and cues to action in the context of influenza vaccination. However, the results of this research must be interpreted while taking the study limitations into consideration. This study population is the result of a convenience sample for which participants self-selected for app use. Comparison of sample demographics with university demographics found statistically significant difference in distributions of measured factors, supporting the hypothesis that selection bias has occurred in this sample. It is possible that app users choosing to participate in the *OutSmart Flu* vaccination research surveys may have perceptions of influenza vaccination that differ from those of non-respondents. We see an increase in proportion of ultimately vaccinated users completing the follow-up survey as compared to the baseline survey, while no other demographic distributions changed significantly during the follow-up period. This finding supports the hypothesis that an

unmeasured “health interest” may encourage continued use of the app in some users after others with lower “health interest” have been lost to follow-up. This phenomenon may lead to biased estimations of associations between the HBM components and the outcome of interest as measured in this study.

This study has several notable strengths including its longitudinal nature, which allows perceptions and intentions to be measured at baseline and changes to be observed over the influenza season. Specifically, the study design allows analysis of perceived barriers overcome within the intention change subgroup; findings which provide important public health direction and generate questions for additional research studies. An additional notable contribution of this research is the smartphone-capture of cues to action. Success of this study component provides support for development of future studies using smartphones or other mHealth approaches for timely capture of cues to action. Advance of cues to action research may have impactful implications for public health interventions.

Table 10. Demographic Comparison of Undergraduate Student Population and Undergraduate OutSmart Flu app Users

Demographic	Undergraduate population		p value χ^2 test
	University (N=27,833) (%)	OutSmart Flu (N=449) N (%)	
Sex			<0.001
Male	(48.5)	150 (33.4)	
Female	(51.5)	299 (66.6)	
Class standing			<0.001
Freshman	(8.3)	95 (12.2)	
Sophomore	(22.0)	87 (19.4)	
Junior	(27.1)	118 (26.3)	
Senior	(42.6)	149 (33.2)	

Accessed: (5.30.2014) http://registrar.wisc.edu/documents/Stats_all_2013-2014Spring.pdf.

Table 11. Demographic Distributions of *OutSmart Flu* Users* (N=787)

Demographic	Study population (N=787) N (%)	Baseline (N=585) N (%)	Follow up (N=188) N (%)	p value χ^2 test
Sex (†/‡/§)				
Male	281 (35.7)	201 (34.4)	68 (36.2)	0.650
Female	490 (62.3)	384 (65.6)	120 (63.8)	
Unreported	16 (2.0)			
Age (†)				
<=18	3 (0.4)	2 (0.3)	1 (0.5)	0.883 (F)
19	63 (8.0)	58 (9.9)	15 (8.0)	
20	88 (11.2)	80 (13.7)	33 (17.6)	
21	112 (14.2)	102 (17.4)	29 (15.4)	
22	118 (15.0)	105 (18.0)	33 (17.6)	
23	72 (9.2)	67 (11.5)	21 (11.2)	
>=24	176 (22.4)	152 (26.0)	52 (27.1)	
Unreported	155 (19.7)	19 (3.3)	5 (2.7)	
School of study (†)				
				0.053
Ag & Life Sciences	135 (17.2)	116 (19.8)	46 (24.5)	
Education	24 (3.1)	20 (3.4)	7 (3.7)	
Engineering	35 (4.5)	29 (5.0)	14 (7.5)	
Human Ecology	13 (1.7)	11 (1.9)	3 (1.6)	
Letters & Science	141 (17.9)	122 (20.9)	36 (19.2)	
Undecided/ undeclared	25 (3.2)	22 (3.8)	12 (6.4)	
Nursing & Pharmacy	18 (2.3)	17 (3.0)	9 (4.8)	
Grad School	55 (7.0)	45 (7.7)	18 (9.6)	
N/A	24 (3.1)	21 (3.6)	8 (4.3)	
Unreported	285 (36.2)	155 (26.50)	27 (14.4)	
Class standing/ affiliation (‡)				
Freshman	-	95 (16.2)	32 (17.0)	0.075
Sophomore	-	87 (14.9)	26 (13.8)	
Junior	-	118 (20.2)	34 (18.1)	
Senior	-	149 (25.5)	43 (22.9)	
Grad student/ Postdoc	-	98 (25.5)	40 (21.3)	
Faculty/ Staff	-	31 (5.3)	5 (2.7)	
Other	-	7 (1.2)	8 (4.3)	
Housing (profile-or at time of survey)				
On-campus res hall	384 (48.8)	134 (22.9)	45 (23.9)	0.629
Near-campus apt/house	137 (17.4)	325 (55.6)	95 (50.5)	
Off-campus/commuter	237 (30.1)	110 (18.8)	42 (22.3)	

Fraternity/Sorority house	10 (1.2)	12 (2.1)	4 (2.1)	
Other	-	4 (0.7)	2 (1.1)	
Unreported	282 (35.8)			
Living companions (at time of survey)				
Student roommates	-	414 (70.8)	127 (67.6)	0.946
Non-student roommates	-	62 (10.6)	19 (10.1)	
Parents/ family	-	56 (5.6)	17 (9.0)	
Other	-	17 (2.9)	7 (3.7)	
Living alone		73 (12.5)	26 (13.8)	
Reported 2013-14 vaccination (†/‡/§)	389 (49.4)	370 (63.3)	148 (78.72)	<0.001
Unreported	398 (50.6)	215 (36.8)	40 (21.28)	

*Demographics as reported in user profile (†), in baseline survey (‡), and in follow-up survey (§). Survey responses combined for immutable variables (i.e. sex, and 2013-14 vaccination)

(F) Fisher's exact test used

Table 12. Factors Associated with Vaccination Decision as Identified by the Health Belief Model

Item	OR [95% CI]
Demographics	
Sex (female)	0.95 [0.43, 2.10]
Undergraduate	0.22 [0.10, 0.97]
Perceived severity to influenza	
If I were to get the flu, my symptoms would be serious.	1.87 [0.84, 4.16]
Perceived susceptibility to influenza	
I am at risk of getting the flu.	1.05 [0.46, 2.64]
Perceived benefits of vaccination	
The seasonal flu vaccine will protect me from the flu.	2.07 [0.95, 4.50]
Perceived barriers to vaccination	
There are reasons why I cannot get the flu vaccine.	0.32 [0.09, 1.18]
Influenza and vaccination history	
Have you ever received the seasonal flu vaccine?	8.19 [3.22, 20.86]
Do you believe you have ever had the flu?	0.34 [0.11, 1.09]

Table 13. Perceived Benefits and Barriers to Vaccination

Benefits at baseline among those ultimately reporting vaccination (N=362)			
<i>How much influence did the following reasons have on your decision to get the vaccine this year?</i>			
	Influence		
	None	Some	Strong
Decrease likelihood of getting the flu	29 (8.0)	83 (22.9)	250 (69.1)
Easy and convenient/ no reason not to	32 (8.9)	126 (34.9)	203 (56.2)
Reduce transmission to relatives/ friends	50 (13.9)	165 (45.7)	146 (40.4)
Reduce transmission to classmates/ coworkers/ strangers	63 (17.5)	179 (49.6)	119 (33.0)
Vaccine is safe and affective	67 (18.5)	150 (41.4)	145 (40.1)
Requirement for work or volunteering position	184 (51.0)	58 (16.1)	119 (33.0)
Having a chronic condition/ being at higher risk	281 (77.6)	46 (12.7)	35 (9.7)
Other	274 (75.7)	76 (21.0)	12 (3.3)

Barriers at baseline among those reporting not having been vaccinated at follow-up (N=40)			
<i>How much influence did the following reasons have on your decision to not get the flu vaccine this year?</i>			
	Influence		
	None	Some	Strong
Prefer other ways to protect against the flu	16 (40.0)	19 (47.5)	5 (12.5)
Worried about the side effects	19 (47.5)	14 (35.0)	7 (17.5)
Do not think myself at risk of getting the flu	20 (50.0)	19 (47.5)	1 (2.5)
Vaccine might give me the flu	20 (50.0)	15 (37.5)	5 (12.5)
Do not think the vaccine is effective	21 (53.9)	11 (28.2)	7 (18.0)
Needle phobia	28 (70.0)	3 (7.5)	9 (22.5)
Inconvenience	28 (70.0)	8 (20.0)	4 (10.0)
Other	30 (75.0)	6 (15.0)	4 (10.0)
Lack of information about the vaccine	34 (85.0)	6 (15.0)	0 (0.0)
Allergies to constituents of vaccine	37 (92.5)	2 (5.0)	1 (2.5)

Table 14. Cues to Action Summarized According to Themes among Respondents (N=167)

Summary of Cues to Action	N (%)
No response	38 (22.8)
Seasonal habit/ approach of flu season	29 (17.4)
Work/School/Volunteer requirement	24 (14.4)
Available at convenient location/time	23 (13.8)
Finding time (follow through on intention)	19 (11.4)
Prompted/directed by family, significant other, friends or roommate	11 (6.6)
Others becoming ill	8 (4.8)
Posters/ Email	7 (4.2)
Unknown cue	7 (4.2)
Free/no barrier	6 (3.6)
Flu shot clinic / walk-ins ending	5 (3.0)
Prior illness	5 (3.0)
Chronic illness/ fear of comorbidity	2 (1.2)
Know someone who got vaccinated/ invited to accompany someone else	2 (1.2)
Vaccine unavailable at other location	2 (1.2)
OutSmart Flu reminders	2 (1.2)
Doctor recommended	2 (1.2)
Altruism	1 (0.6)
Approach of important event	1 (0.6)
Feeling sick	1 (0.6)
“Personal choice”	1 (0.6)

Table 15. Barriers to Vaccination as Perceived at Baseline among Participants with Vaccination Intention Change

Barriers at baseline (among those having reported 'unsure' vaccination intent (N=13))			
<i>In general, how much influence would the following reasons have on your decision to not get the flu vaccine?</i>			
	Influence		
	None	Some	Strong
Inconvenience	3 (23.1)	4 (30.8)	6 (46.2)
Vaccine might give me the flu	3 (23.1)	7 (53.9)	3 (23.1)
Worried about the side effects	3 (23.1)	7 (53.9)	3 (23.1)
Do not think myself at risk of getting the flu	5 (38.5)	6 (46.2)	2 (15.4)
Prefer other ways to protect against the flu	5 (38.5)	7 (53.9)	1 (7.7)
Do not think the vaccine is effective	5 (38.5)	7 (53.9)	1 (7.7)
Needle phobia	8 (61.5)	3 (23.1)	2 (15.4)
Lack of information about the vaccine	8 (61.5)	5 (38.5)	0 (0.0)
Other	9 (69.2)	3 (23.1)	1 (7.7)
Allergies to constituents of vaccine	10 (76.9)	1 (7.7)	1 (2.5)
Barriers at baseline (among those having reported 'no' vaccination intent N=5)			
<i>How much influence did the following reasons have on your decision to not get the flu vaccine this year?</i>			
	Influence		
	None	Some	Strong
Inconvenience	1 (20.0)	3 (60.0)	1 (20.0)
Prefer other ways to protect against the flu	1 (20.0)	4 (80.0)	0 (0.0)
Worried about the side effects	2 (40.0)	2 (40.0)	1 (20.0)
Do not think the vaccine is effective	2 (40.0)	2 (40.0)	1 (20.0)
Vaccine might give me the flu	2 (40.0)	3 (60.0)	0 (0.0)
Needle phobia	3 (60.0)	2 (40.0)	0 (0.0)
Other	4 (80.0)	1 (20.0)	0 (0.0)
Lack of information about the vaccine	5 (100.0)	0 (0.0)	0 (0.0)
Allergies to constituents of vaccine	5 (100.0)	0 (0.0)	0 (0.0)
Do not think myself at risk of getting the flu	5 (100.0)	0 (0.0)	0 (0.0)

**Table 16. Cues to Action Reported among Participants with Vaccination Intention Change
among those having reported 'unsure' vaccination intent (N=13)**

"My sister asked me to go with her, which gave me more motivation to go"

"I happened to be at the clinic so I stopped in"

"an email"

"My dad was concerned since he has been seeing flu cases in South Beloit"

"Family reasons"

"Free shots, figured why not"

"I noticed so many people getting sick around me"

among those having reported 'no' vaccination intent (N=5)

"Just did it"

"I was visiting the doctor for another incident and got the shot while I was there"

"My family pressured/ suggested I get it"

"I weighed the inconvenience against to the contribution to herd immunity"

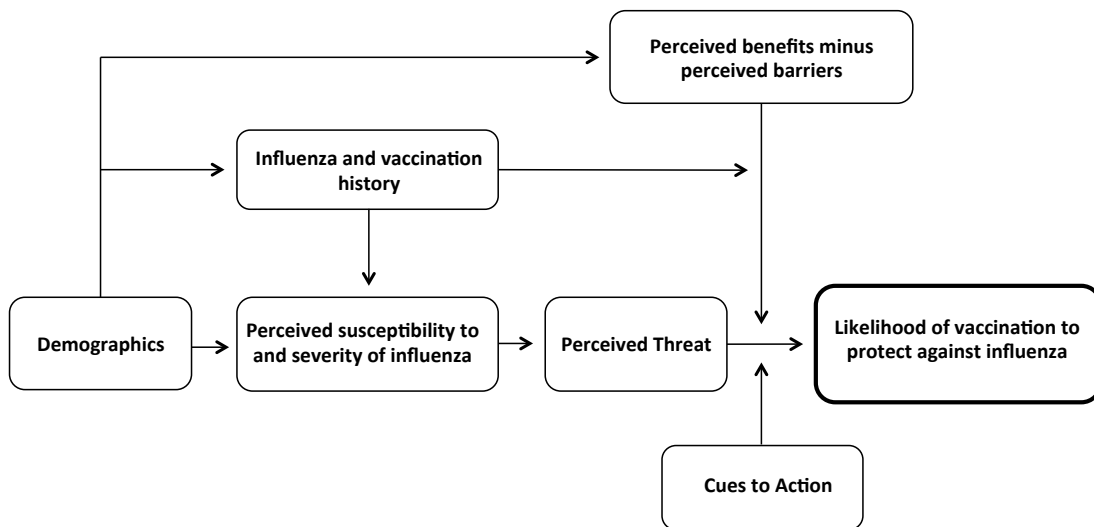


Figure 4. Conceptual Model of Factors Relating to Influenza Vaccination

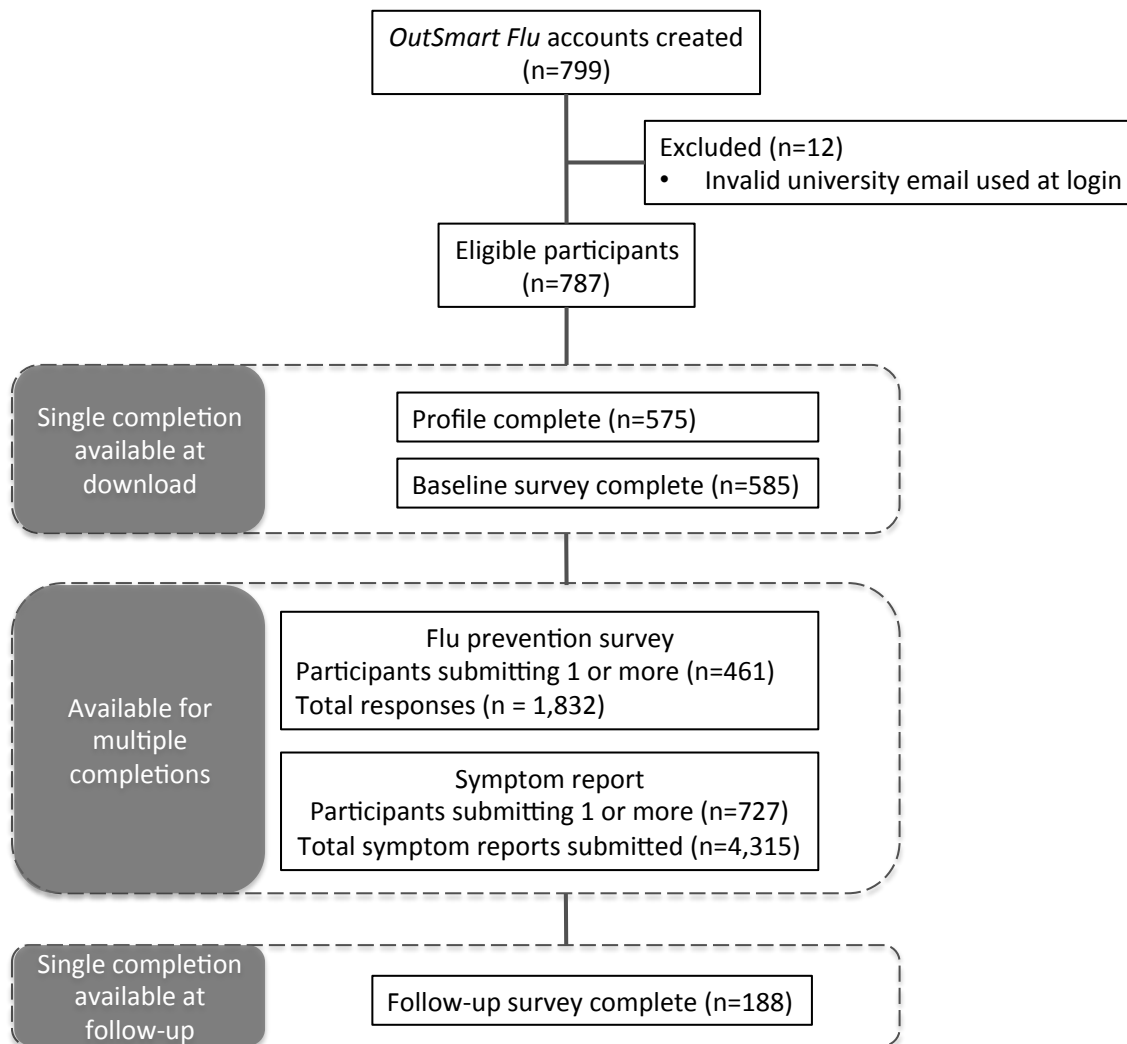


Figure 5. User Engagement with *OutSmart Flu* app Components

Chapter 6: Findings from a 2013-14 Influenza Surveillance

Crowd-sourcing Initiative

Introduction

Surveillance data provide an essential guide in the development and implementation of influenza prevention and control programs. Currently, the U.S. Outpatient Influenza-like Illness Surveillance network (ILINet) serves as the gold standard for influenza surveillance in the United States. ILINet is a collaboration between the Centers for Disease Control and Prevention (CDC) and over 2,900 outpatient clinics distributed across the nation responsible for conducting syndromic surveillance for influenza. As a condition for inclusion, ILINet surveillance data requires an outpatient visit with symptoms symptomatic of the CDC case-definition of influenza-like illness (ILI) (i.e., fever over 100°F with cough and/or sore throat in the absence of an alternate diagnosis) (Centers for Disease Control and Prevention, 2014b). Challenges to this system include the ten- to fourteen-day reporting lag and underrepresentation of milder cases of ILI. These limitations may prevent the detection of early outbreak signs and may lead to initial overestimations of the severity of the circulating strains (Garske et al., 2009) .

Alternatives to the ILINet syndromic surveillance system have been explored to address these shortcomings. Proposed sources of influenza surveillance data have included emergency department and absenteeism reports, health advice calls, web queries, and pharmaceutical sales (Heffernan et al., 2004; Dailey et al., 2007).

Pharmaceutical sales data have been harnessed with some success as a timely alternative to syndromic surveillance systems such as ILINet. Studies have found over-the-counter

flu remedy sales to accurately predict physician diagnoses of acute respiratory conditions with three days lead-time (Magruder, 2003), and estimates of influenza rates generated from flu prescription sales correlate closely with those of ILINet and other established surveillance systems (Patwardhan and Bilkovski, 2012). However, these methods raise concern due to biased detection of cases according to symptom severity and socioeconomic status, as well as potential loss of specificity due to self-diagnosis in the case of over-the-counter treatments (Patwardhan and Bilkovski, 2012). In November of 2008, Google launched an internet-based approach to influenza surveillance: Google Flu Trends (GFT) uses an automated query-selection process to identify ILI-related searches without requiring the searcher to have any previous knowledge about influenza (Google.org, 2008; Carneiro and Mylonakis, 2009). This aggregate search engine data is then used to detect influenza epidemics and predict outpatient visits due to ILI. Web queries often occur prior to clinic visits and can be processed quickly such that ILI surveillance estimates consistently preceded CDC reports by one to two weeks in the GFT pilot. An advantage of the GFT approach is the extensive availability of search engines, decreasing opportunity for selection bias introduced by clinic-based methods. (Ginsberg et al., 2009). GFT has demonstrated the ability to detect outbreaks seven to ten days earlier than conventional CDC surveillance systems (Carneiro and Mylonakis, 2009), and to produce estimates of ILI rates strongly correlating with ILINet data (Ortiz et al., 2011). GFT may enable timely public health response through early alert in the case of outbreaks; however, researchers caution reliance on GFT in place of local surveillance, as the nonspecific nature of the GFT model cause susceptibility to overestimation (Cook et al., 2011; Eysenbach, 2006; Ginsberg et al., 2009; Olson et al.,

2013). GFT surveillance data is susceptible to errors introduced by changes in search behavior in response to media and other external events; especially in the case of epidemics when healthy individuals may also be driven to information seeking. In February 2013, GFT was found to be over reporting rates of outpatient visits for ILI by a factor of two, as compared to ILINet data (Butler, 2013; Lazer et al., 2014). A further limitation of the GFT approach is the absence of demographic information, which is helpful for implementation of control and prevention measures. While GFT may be used effectively to detect aberrations and outbreaks, the current algorithms are inappropriate for the estimation of influenza rates.

Smartphones and Current Usage

The recent advance of smartphones has opened numerous opportunities for the development and introduction of novel health interventions. These mobile phones have capabilities beyond standard voice and text communication extending to Internet access, geographical positioning systems, and computational capacities. Numerous smartphone apps have been introduced to improve health interventions; indirectly, through data collection for healthcare improvement research, or directly, in the form of modified implementations to existing interventions. Of the hundreds of available smartphone apps designed for health impact, reviews have found the most successful apps to be those designed for younger and healthier populations (Boulos et al., 2011). This finding is likely due to the comparatively slower uptake of smartphones (and consequently, smartphone-based interventions) by older individuals and those with chronic diseases.

Among university students, prevalence of smartphone ownership is continually rising, and increasingly, smartphone owners are utilizing these devices to inform health behavior

decisions. Based on past trends, it is estimated that 90% of university students in the United States are currently smartphone owners – a statistic that is forecast to plateau in 2014 (Hanley and Becker, 2012) . The high prevalence of smartphone ownership, and frequent-use patterns (Bomhold, 2013), may provide an opportunity for successful health interventions within university student populations. We propose a method utilizing smartphones to enable reporting of ILI-specific symptoms; provide users with relevant ILI-related education; and produce demographic-specific, near-real time estimates of ILI rates. The aim of this study is to summarize findings from the 2013-14 *OutSmart Flu* influenza surveillance smartphone app study, through comparison of observed ILI rates with established surveillance systems. This study seeks to evaluate the potential for smartphone engagement to capture ILI syndromic surveillance data, and identify best practices for this system within a university student population.

Methods

This study used data from the smartphone app-based component of the *OutSmart Flu Influenza Surveillance & Research Initiative*. The *OutSmart Flu* app provided users with an interface to report real-time presence or absence of ILI symptoms, and access to updated ILI campus trends and influenza prevention tips. The study was conducted on the University of Wisconsin-Madison campus from September 20, 2013 to May 31, 2014; the study period corresponded to CDC influenza surveillance weeks 39 through 22 of the 2013-14 season (Figure 6). Development of the *OutSmart Flu* project was advised by health researchers, and physicians and staff of the university student health center (SHC). This study was approved by the Institutional Review Board at the University of Wisconsin-Madison (IRB 2013-0658).

Study Population, Recruitment & Enrollment

Study participants were defined as app users age seventeen or older, having verified receipt of the study information sheet, and completed successful account set up with a university issued email address login. Enrollment was rolling throughout the study period; eligible individuals were able to join the study at any time. Undergraduate students were targeted for recruitment due to their higher use of the SHC and heightened risk of influenza infection due to close interactions in residence halls and other shared spaces. Students in residence halls and large, entry-level classes were targeted for recruitment on the basis of convenience.

app Specifications & Survey Management

Specifics of *OutSmart Flu* features relevant to surveillance are provided below; refer to Chapter 2 for complete detailed description of *OutSmart Flu* design and app components.

Symptom Reporting

Symptomatic participants had the option to report symptoms as experienced; similarly, asymptomatic participants had the ability to report absence of ILI symptoms at any time. To conduct syndromic surveillance, *OutSmart Flu* participants were asked to use a brief survey (completion time less than 30 seconds) to report presence or absence of ILI symptoms throughout the influenza season (Figure 7). The symptom survey presented participants with a screening question asking, “How are you feeling?” with the option to select either “healthy” or “sick”. Users reporting feeling sick were presented with an ILI symptom index and asked to select the symptoms experienced. In accordance with the ILI definition in use at the SHC, the standard CDC symptom-based case definition of ILI was

used (measured fever over 100°F with cough and/or sore throat); participants were asked to enter the highest measured temperature to provide objective symptom assessment of fevers. This survey was available within 24 hours of account set-up to all users and remained available for multiple completions with unlimited frequency for the duration of the study period.

Campus-level ILI Report

The health status submitted via symptom report triggered a message with relevant health information (see Appendix A.4 for messages). All users reporting symptoms consistent with the CDC definition of ILI were notified immediately that their symptom report was consistent with ILI, reminded that *OutSmart Flu* does not constitute health care, and were referred to the SHC website for self-care instructions; students with more severe symptoms were instructed to seek healthcare if they would usually do so.

Any symptom report submission (either “healthy” or “sick”) triggered a report of the estimated campus prevalence of ILI as estimated by *OutSmart Flu* reports within the past seven days, with the previous week’s SHC weekly report of ILI included for comparison (see Appendix A.4 for template). Thus, users were able to “request” updated surveillance data at any time through the submission of a symptom report. The estimated prevalence was updated daily and reported campus rates were monitored consistently for any significant increase in case numbers.

Daily Processing of Symptom Reports

To update the ILI surveillance summaries, data was downloaded daily from the symptom report survey and manipulated using MS Excel (Microsoft, Redmond, WA).

Code was written and executed using Stata version 13.1 (StataCorp, College Station, TX) to determine ILI incidence during the past seven days. The final page of the symptom report survey was updated with the latest ILI summary and the new version was pushed to the *OutSmart Flu* participants.

ILI Case Definition

Following the definition used by the CDC and the SHC, an ILI report was defined as a symptom report including measured fever over 100°F with cough and/or sore throat. For these analyses, a possible case was defined as a report of unmeasured fever with cough and/or sore throat.

ILI Rate Comparisons

The SHC for this study population serves as a sentinel site for ILInet surveillance, and is used in this research as a comparison for estimated rates of ILI. Campus ILI rates are estimated per week from the number of SHC visits resulting in a diagnosis of ILI, using the total number of SHC visits as a denominator. In this study, *OutSmart Flu* estimates of campus-level ILI rates were calculated from unique ILI reports per person, per week, using the total number of unique per person reports for that week as the denominator.

Statistical Analyses

The *OutSmart Flu* study population was characterized according to measured demographics. Demographic distributions of the *OutSmart Flu* population undergraduate student status at baseline were compared to campus-level undergraduate demographics as reported by the registrar. To identify demographic factors associated with submission of

any symptom report regardless of health status, χ^2 , Fisher's exact and t-tests were used as appropriate. Symptoms were summarized independently according to frequency of report during the study period; additionally, frequency of reports of symptoms characteristic of ILI were summarize graphically. An epidemiological curve was constructed to summarize reported ILI cases over time and was compared to surveillance data gathered via established methods (i.e., SHC campus-level surveillance). Wilson confidence intervals were constructed around the *OutSmart Flu* surveillance data to identify statistically significant deviations from SHC surveillance. A logistic model was used to regress grouped SHC ILI surveillance rates on *OutSmart Flu* surveillance by CDC week. This model was repeated regressing SHC surveillance data on *OutSmart Flu* surveillance from the previous CDC week to investigate potential lead-time in ILI reporting. Logistic regressions included a dummy variable indicating the winter break time period. Based on sample size obtained during the initial season of *OutSmart Flu*, power calculations were performed to determine the system potential for outbreak detection in this context. All analyses were conducted using Stata version 13.1.

Results

Among *OutSmart Flu* app users, 787 met the participant eligibility criteria (twelve additional users registered with invalid credentials and were excluded from analyses). The total study population was comprised of 281 (35.7%) males, 490 (62.3%) females, and 16 (2.0%) individuals of unreported sex. The subpopulation of undergraduate *OutSmart Flu* users was not found to be comparable with the university undergraduate population in terms of measured demographics (Table 17). Demographic distributions of participants did not vary significantly according to sex, age, university affiliation,

housing, or living companions over follow-up, as shown in comparisons between the baseline surveys delivered at enrollment and the follow-up survey (Appendix D.1). The sub-sample of participants submitting one or more symptom reports was comprised of a larger proportion of female participants and participants reporting vaccination as compared to the study population. Participants reporting ages 24 or older were more likely to submit one or more symptom reports as compared to other age groups (Table 18).

A total number of 22,352 symptom reports were submitted to *OutSmart Flu* during CDC surveillance weeks 39 – 22 of the 2013-14 influenza season. In this study, a possible case of ILI was defined as report of an unmeasured fever with cough and/or sore throat. Of all reports, 1,617 (7.2%) included report of any illness, 73 (0.3%) report of possible ILI, and 46 (0.2%) reports met the CDC criteria for ILI. Unique reports per person, per week included 802 (3.6%) reports of any illness, 67 (0.3%) reports of possible ILI, and 35 (0.2%) reports classified as ILI. Symptoms most commonly reported over all reports of illness included runny and/or stuffy nose (70%), fatigue (55%), and sore throat (52%), symptoms least frequently reported included fever (17%), unspecified “other symptom” (13%), diarrhea (9%) and vomiting (6%) (Table 19; Figure 8)

The first case of ILI was reported to *OutSmart Flu* on September 29, 2013 and the last case was reported on April 21, 2014. The first report of possible ILI was submitted on September 24, 2013, and the last report of possible ILI was submitted on May 14, 2014. The peak rate of ILI as captured by SHC surveillance occurred at 3.9% during CDC week 50. The peak rate of ILI as captured by *OutSmart Flu* surveillance occurred at 3.4% during CDC week 5 (Figure 9; Figure 10).

During the 2013-14 influenza season, the peak of activity occurred during the end of December, a time period overlapping with the academic calendar's winter break (CDC surveillance weeks 52–3). SHC and *OutSmart Flu* surveillance experienced a decrease in activity during this time period, with a local maximum occurring on the epidemic curves as students returned to campus and classes. The epidemiological curve shows SHC surveillance data in relation to *OutSmart Flu* surveillance data with the regional baseline (Centers for Disease Control and Prevention, 2014b) shown as reference (Figure 11). Inclusion of Wilson confidence intervals illustrates lack of statistically significant difference in signal between surveillance systems; specific interval values are listed in Appendix D.2. Logistic regression of weekly SHC surveillance data on *OutSmart Flu* surveillance data showed no significant association between observed ILI levels in the same surveillance week; further, *OutSmart Flu* surveillance data was not found to be a significant predictor of SHC surveillance for the following surveillance week (Table 20). *OutSmart Flu* surveillance was not found to significantly predict or correlate with SHC surveillance data in the 2013-14-season pilot.

Timing and characteristics of the 2013-14 influenza seasons did not present opportunity for practical evaluation of *OutSmart Flu* potential for outbreak detection. Power calculations based on baseline levels of ILI for the region (1.7%) and nation-wide (2.0%), were performed to construct estimations of the system potential for outbreak detections. During the 2013-14 influenza season, *OutSmart Flu* enrolled 787 participants with an average of 98 unique symptom reports per week. ILI thresholds are shown for sample sizes of 100-1,000 unique reports per week to detect a change from the baseline at

minimum 80% power (Figure 12). An effect of diminishing returns is evident as sample size is increased.

Discussion

During the 2013-14 influenza season, *OutSmart Flu* was moderately successful in recruiting users and maintaining user engagement. The initiative showed promise for the success of health apps within a university population. Demographic composition of the user population found women to be more likely, as compared to men, to download the app and submit one or more symptom reports. Age and vaccination status were also associated with *OutSmart Flu* use; older students, and vaccinated students were more likely to download and use the app. Due to timing and mild severity of the influenza season, as well as sample size limitations, *OutSmart Flu* was unable to detect an ILI outbreak during the 2013-14 season.

A significant strength of syndromic surveillance by smartphone is the potential for increased sensitivity in surveillance. In contrast to traditional methods, this approach does not require a clinic-visit as a prerequisite for inclusion, and may therefore allow detection of mild cases of ILI when medical care is not sought. However, this study uncovered several additional threats to increased sensitivity in ILI surveillance. Comparison with established ILI surveillance requires the common use of the CDC ILI definition, which requires a measured temperature for inclusion. *OutSmart Flu* surveillance data show that students are more likely to report an unmeasured fever than a measured fever in the presence of other ILI symptoms. Lack of measured temperature may prevent additional ILIs from meeting the case definition. As smartphone capabilities progress, it may later become feasible for students to measure their temperature using a smartphone sensor;

however, at this time many students may require a clinic-visit to obtain a measured temperature. Although reported rates of measured and unmeasured fevers appeared comparable in *OutSmart Flu* data, the combination of these symptoms did not provide sufficient power to predict SHC surveillance data in logistic models. This finding supports the theory that required measured temperature as a condition for inclusion as a case did not result in a significant loss of sensitivity in this study.

Another threat to increased sensitivity is a potential effect of health-motivated users. Individuals may choose to participate in *OutSmart Flu* surveillance due to an underlying “health interest”, and as observed in this study, may be more likely to obtain the seasonal vaccine as compared to the general student population. This self-selection may lead to a healthier cohort of reporters and fewer cases of ILI to detect within this group. Formative research has suggested that smartphone apps for health may be useful provided that the user has prior commitment to engage in the encouraged behavior, but may be ineffective or irritating in the absence of pre-existing, or intrinsic motivation (Dennison et al., 2013). Further, the nature of the *OutSmart Flu* app may have compounded the health-motivated user effect. This study lacked ability to measure interventional effects of app usage, however, theories of behavioral change would suggest potential for access to surveillance data to result in altered perceptions of ILI susceptibility, and ultimately impact health behaviors such as hand washing and vaccination. Future studies are needed to investigate any interventional effects of the *OutSmart Flu* app; understanding behavioral responses to the presentation of proximal infectious disease surveillance data will be crucial in future developments of impactful health apps.

The selection for health-motivated users may pose a major challenge to the accurate estimation of ILI rates; however, this phenomenon constitutes a strength in the aim of outbreak detection. The sample of symptom reporters need not be representative of the campus to detect aberrations from an established baseline. If used for outbreak detection, *OutSmart Flu* surveillance may harness the interest of individuals with vested health interest, mirroring the ILInet approach with health conscious individuals serving as sentinels and reporting incidence of ILI on behalf of the campus population. If used exclusively for outbreak detection, future generations of the *OutSmart Flu* app might include an additional question asking the user to report knowledge of anyone else who has experienced ILI-specific symptoms.

Timeliness is valuable in surveillance systems for outbreak detection. The *OutSmart Flu* model has the potential to detect outbreaks earlier as compared to traditional methods; however, the potential lead-time is unknown. In this study, SHC data was aggregated by CDC week, resulting in inability to test possibilities of an average lead-time less than seven days. Assume a difference of less than one week between symptom onset (earliest possibly *OutSmart Flu* report) and progression of symptoms prompting SHC clinic visit, to the end of the next CDC reporting week. In this case, adjustments of one week lead-time for *OutSmart Flu* surveillance data as a predictor in logistic models, may have resulted in an over adjustment. Further research is needed to determine the timeliness of this method.

Another notable strength of the *OutSmart Flu* approach for outbreak detection is its potential ability to measure illnesses occurring among students during academic periods such as winter break that enable students to travel off-campus during a time when

influenza outbreaks may occur. Monitoring ILI rates among students both on- and off-campus during high travel periods may provide a valuable supplement to university-based, outpatient surveillance, and inform preparedness measures as ill students return to campus following a recess. To capitalize on this potential, students must be encouraged to continue symptom reporting during peak travel times.

In the context of outbreak detection, the effects must be considered of waning app engagement associated with time since enrollment. To establish baseline levels of illness, student interest must be maintained during non-peak seasons and during academic breaks. To decrease the impact of waning app engagement, app promotion and recruitment might be delayed until later in the season so as to retain sample size sufficient for aberration detection when the outbreak occurs. However, due to unpredictable timing of annual epidemics, this goal poses a significant challenge. An alternate approach may be to intensify app recruitment as the season progresses.

Limitations such as the effect of health-motivated users and waning user interest pose significant challenges to estimation of ILI rates sustained over an academic year using this smartphone approach. However, rates of symptom reporting during the *OutSmart Flu* pilot suggest evidence for this system to be used in outbreak detection assuming adequate sample size. Due to the absence of an observable peak in influenza activity this season, continued research is needed during future seasons to better determine the ability for a smartphone app to detect influenza outbreaks in a university setting.

Table 17. Comparison of Demographic Information for Undergraduate University Population and OutSmart Flu Undergraduate Population

Demographic	Undergraduate population		p value χ^2 test
	University (N=27,833) N(%)	OutSmart Flu (N=449) N (%)	
Sex			<0.001
Male	(48.5)	150 (33.4)	
Female	(51.5)	299 (66.6)	
Class standing			<0.001
Freshman	(8.3)	95 (12.2)	
Sophomore	(22.0)	87 (19.4)	
Junior	(27.1)	118 (26.3)	
Senior	(42.6)	149 (33.2)	

Accessed: (5.30.2014) http://registrar.wisc.edu/documents/Stats_all_2013-2014Spring.pdf.

Table 18. Demographics of Study Participants according to Reporting Status

Demographic	Study population (N=787) N (%)	Symptom Reporters (N=535) N (%)	p value χ^2 test
Sex (†/‡/§)			
Male	281 (35.7)	180 (33.6)	0.015
Female	490 (62.3)	355 (66.4)	
Unreported*	16 (2.0)	0 (0.0)	
Class standing/ affiliation (‡)			
Freshman	95 (12.1)	80 (16.4)	0.312
Sophomore	87 (11.1)	69 (14.2)	
Junior	118 (15.0)	93 (19.1)	
Senior	149 (18.9)	123 (25.3)	
Grad student	97 (12.3)	88 (18.1)	
Postdoctoral training	1 (0.1)	1 (0.2)	
Staff	23 (2.9)	20 (4.1)	
Faculty	8 (1.0)	8 (1.6)	
Other	7 (1.0)	5 (1.0)	
Unreported*	202 (25.7)	48 (9.0)	
School of study (†)			
Ag & Life Sciences	135 (17.2)	110 (20.6)	0.095
Education	24 (3.1)	19 (3.6)	
Engineering	35 (4.5)	27 (5.1)	
Human Ecology	13 (1.7)	9 (1.7)	
Letters & Science	141 (17.9)	112 (20.9)	
Undecided/ undeclared	25 (3.2)	25 (4.7)	
Nursing	12 (1.5)	12 (2.2)	
Pharmacy	6 (0.8)	6 (1.1)	
Grad School	55 (7.0)	45 (8.4)	
N/A	24 (3.1)	20 (3.7)	
Unreported*	285 (36.2)	122 (22.8)	
Housing (†/‡/§)			
On-campus res hall	138 (23.3)	117 (23.6)	0.8
Near-campus apt/house	329 (55.5)	273 (55.2)	
Off-campus/commuter	110 (18.6)	92 (18.6)	
Frat/Sorority house	12 (2.0)	9 (1.8)	
Other	4 (0.7)	4 (0.8)	
Unreported*	194 (24.7)	40 (7.5)	

Reported 2013-14 vaccination	389 (49.4)	350 (65.4)	<0.001
Vaccination status unreported	398 (50.6)	185 (34.6)	

Demographics as reported in user profile (†), in baseline survey (‡), and in follow-up survey (§). Survey responses combined from all surveys for immutable variables (i.e. sex, and 2013-14 vaccination).

*Unreported categories excluded from χ^2 tests.

Table 19. Frequency of Symptoms Included in Reports of Illness

	Illness reports N (%)	ILI reports N (%)	Possible ILI reports N (%)
Fever	140 (17.4)	35 (100)	67 (100)
Cough	311 (38.7)	26 (74.3)	44 (65.7)
Sore throat	421 (52.4)	33 (94.3)	57 (85.1)
Runny/stuffy nose	565 (70.4)	26 (74.3)	52 (77.6)
Muscle/ body aches	230 (28.6)	29 (82.9)	44 (65.7)
Headache	343 (42.7)	28 (80.0)	54 (80.6)
Fatigue	443 (55.2)	30 (85.7)	58 (86.6)
Vomiting	46 (5.7)	4 (11.4)	7 (10.5)
Diarrhea	68 (8.5)	6 (17.1)	11 (16.4)
Other symptom	100 (12.5)	3 (8.6)	12 (17.9)

Table 20. Logistic Regression of Grouped SHC Surveillance Data

Surveillance rate used as predictor*	OR [95% CI]	p value (β)
OutSmart Flu ILI rates	0.815 [0.658, 1.010]	0.061
OutSmart Flu ILI and possible ILI combined	0.840 [0.694, 1.017]	0.074
OutSmart Flu ILI rates (1-week lag)	1.112 [0.900, 1.374]	0.325

*All logistic models included an indicator variable for CDC weeks corresponding to the academic winter break

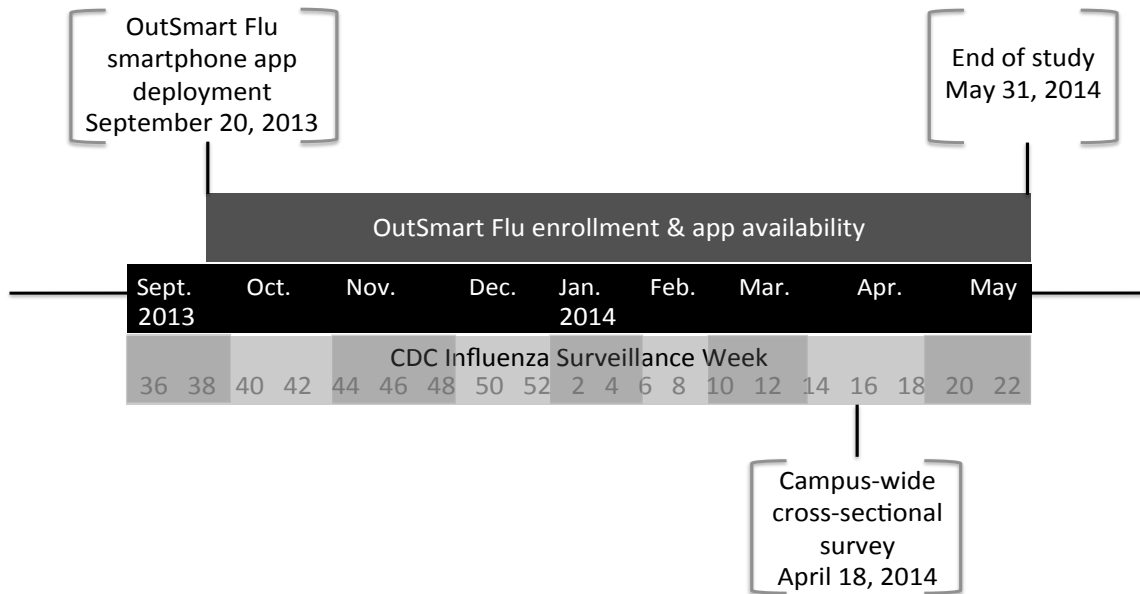


Figure 6. Timeline of *OutSmart Flu* Components by Calendar and CDC Week

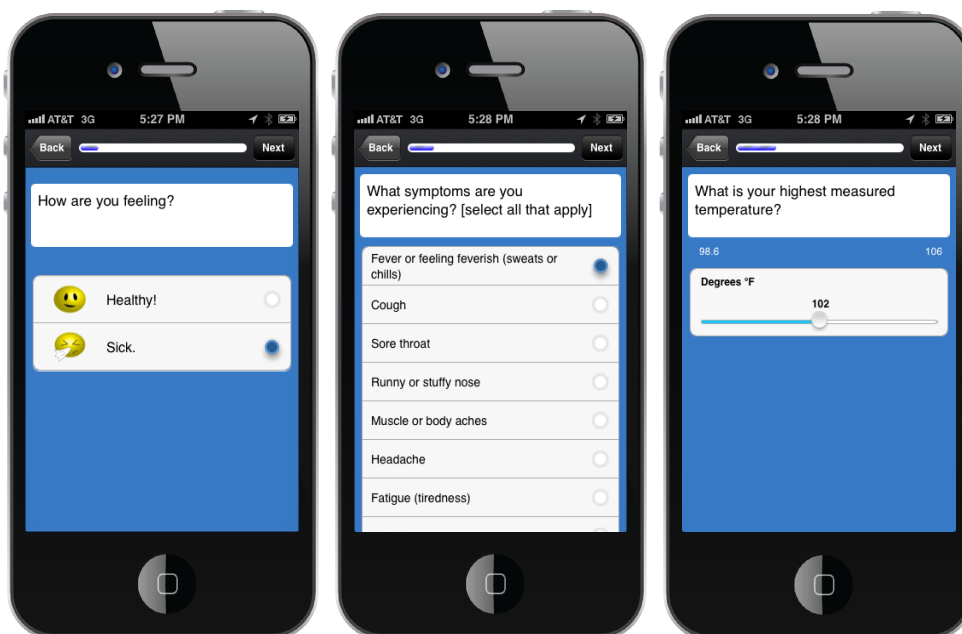


Figure 7. *OutSmart Flu* Symptom Report app Screens

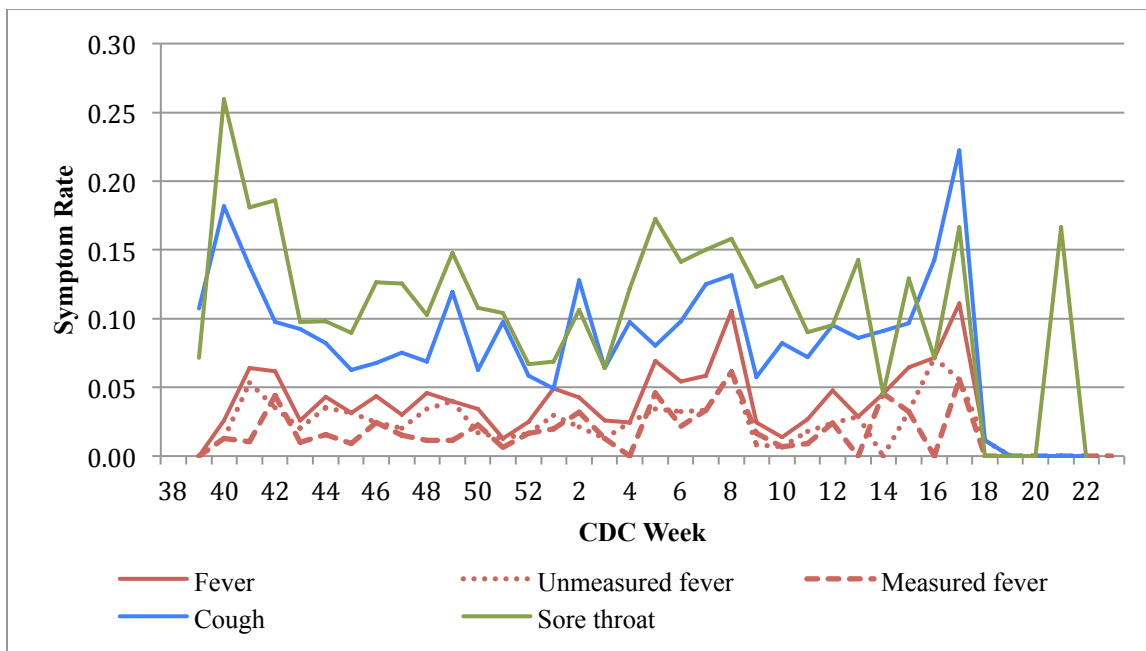


Figure 8. Rates of ILI-specific Symptoms among *OutSmart Flu* Symptom Reports

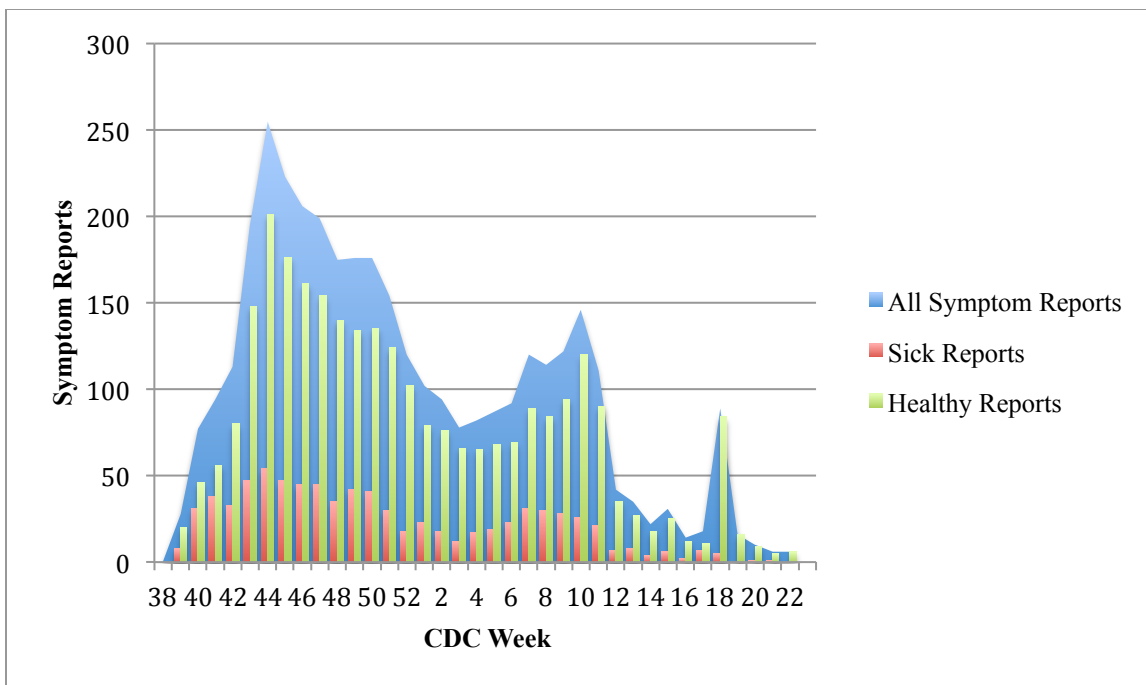


Figure 9. Symptom Reports Submitted to *OutSmart Flu* during 2013-14 Influenza Season

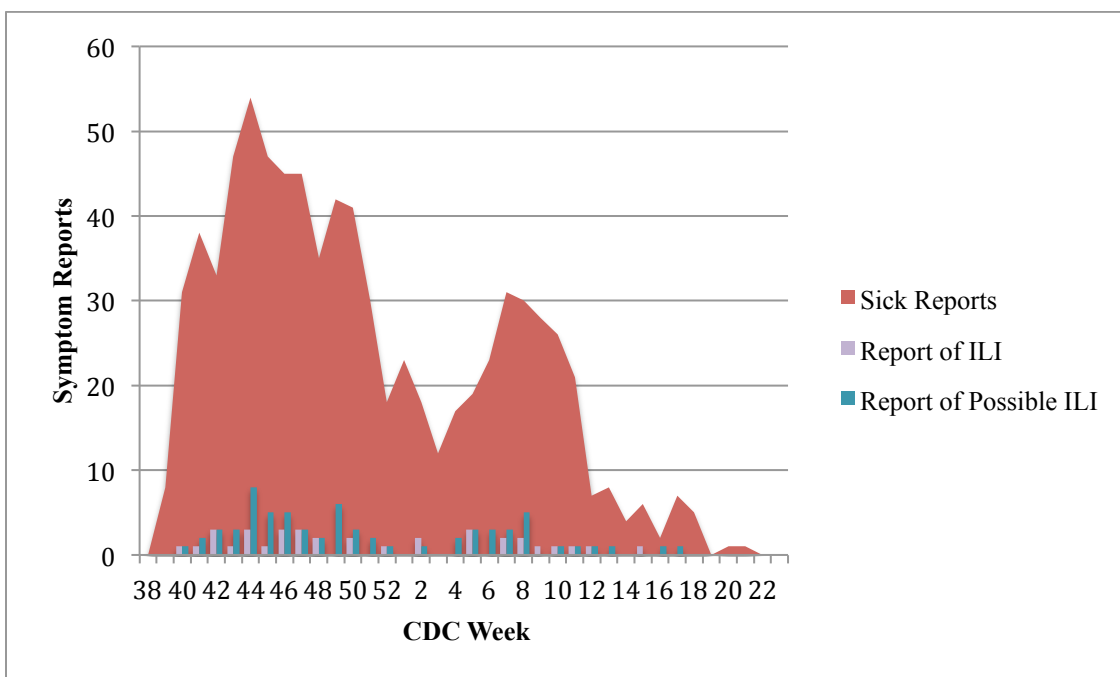


Figure 10. Reports of Illness Submitted to *OutSmart Flu* during 2013-14 Influenza Season

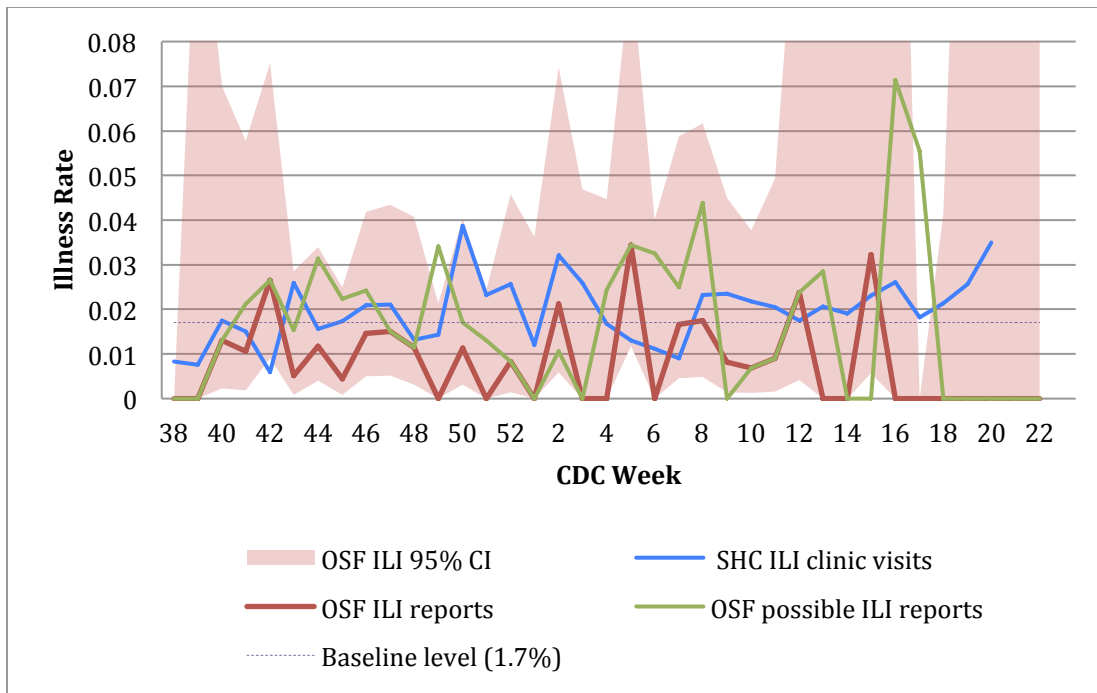


Figure 11. Rates of ILI by Date of Detection for Clinic-based and *OutSmart Flu* (OSF) Surveillance

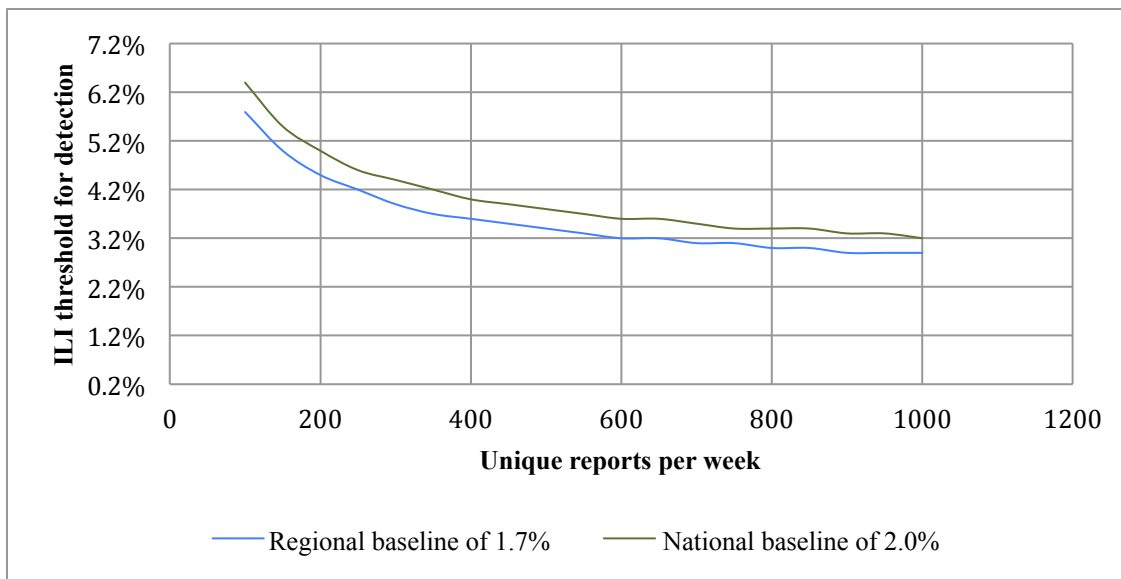


Figure 12. ILI Rate Threshold for Outbreak Detection at 80% Power by Number of Unique OutSmart Flu Reports per Week ($\alpha=0.05$ for all sample size calculations)

Chapter 7: Synthesis

Summary

The main intent of this dissertation was to evaluate the potential for a smartphone-based syndromic surveillance system to improve sensitivity and timeliness of ILI estimates within a university population. This dissertation also seeks to characterize influenza vaccination practices in a population of university students, to identify the relative influence of specific benefits and barriers to vaccination as perceived by vaccinated and unvaccinated subpopulations, and to capture and characterize cues to action influential in the vaccination decision. A particular strength of this innovative work is its theoretical foundation in conjunction with intentional integration of evidence-based practices.

Surveillance

Current ILI surveillance methods rely on clinic-visits as a prerequisite for inclusion in case counts. Participatory surveillance via smartphone offers potential for the scope and timeliness of ILI surveillance to be improved. The approach piloted in this work relied on voluntary symptom reports submitted by *OutSmart Flu* app users to estimate ILI rates. The mild severity of the 2013-14 influenza season, as well as sample size limitations, made conclusive assessment of *OutSmart Flu* capability for ILI surveillance difficult in evaluation of the *OutSmart Flu* app. Effects of self-selection favoring health-motivated app users may have decreased the proportion of actual ILIs experienced by app users and further increased difficulty for ILI rate estimation. However, no statistically significant difference was found between signals detected by *OutSmart Flu* and clinic-based data

generated by the university SHC, even under the milder conditions of the 2013-14 season.

The next step for this research is to repeat the study during a flu season more severe in terms of peak ILI rates. Continued research during future flu seasons will allow better determination of the ability for a smartphone app to detect outbreaks and accurately estimate ILI rates within this population. Further research is needed to explore the opportunity for the *OutSmart Flu* surveillance model to be adapted and generalized to other surveillance situations including other communicable diseases, and chronic conditions relying on syndromic surveillance; these may include emergency symptom monitoring of patients exposed to infectious agents, depression and mental health monitoring for at-risk individuals, or possibly means of reporting unsafe environmental conditions or occurrences of sexual assault. The model is flexible and holds much promise for future developments and directions.

Vaccination

Estimation of vaccination rates is important in the direction and implementation of public health campaigns to encourage vaccine uptake. Further, an understanding of what factors may be effective in encouraging an individual to seek vaccination, and what factors may act as barriers to vaccination, is vital in targeting resources appropriately to maximize perceived benefits of vaccination, create cues to action leading to vaccination, and minimize perceived vaccination barriers. While vaccination rates on university campuses are currently well below levels needed to support herd immunity, findings of this research suggest promise for behavioral change. It is recommended that vaccination campaigns target freshmen, not only to increase coverage among a demographic most

likely to be at heightened risk due to exposure in residence halls, but also to purposefully impact students likely reaching a transition point in their health practices. Encouraging freshman to adopt vaccination as part of their annual preventative health practices, introduces the potential to impact campus-wide vaccination rates the duration of student tenure.

This work identified influential barriers to vaccination and creates a basis for understanding effective cues to action; however, more research is needed to further refine the modified health belief model as proposed in this dissertation. A better understanding of interrelations between model domains (including investigation of possible moderator or mediator relationships) is key to targeting interventions to impact the vaccination pathway at points maximizing effectiveness and efficiency.

Intervention

The Health Belief Model – the theoretical foundation for this research—provides basis for conceptualization of the interventional effects of the *OutSmart Flu* research and surveillance initiative. Specifically, the app newsfeed providing flu prevention tips, as well as the campus-level estimated ILI rates provided in response to symptom reports created opportunity for introduction of cues to action toward health behaviors, in addition to potential impacts on perceived susceptibility to influenza. While this study did not directly measure interventional effects, 64% of participants surveyed at follow-up indicated plans to utilize the app during the 2014-15 influenza season, and 45% indicated that participation in the study had altered their knowledge and/or opinions about the flu (Appendix E.1). These findings support continued research for the use of smartphones to impact health, especially in university populations where acceptance of mHealth

interventions is likely to be relatively high as compared to the general population of smartphone owners. Future iterations of the *OutSmart Flu* app may prove more impactful for health behavior decisions if designed to house only surveillance and interventional components. A streamlined app free of research components is likely to generate improvement in response rates and user retention due to reduced burden on the users. Further research is needed to quantitatively assess the potential for smartphone-driven impact on rates of flu prevention behaviors, and ultimately ILI transmission within university campus populations.

Conclusion

The findings from the *OutSmart Flu* initiative show promise for the success of purposefully designed health apps within a university population and can inform both public health interventions and mHealth literature.

The use of smartphones for surveillance, research, and intervention has several notable strengths. The high penetrance of these devices on university campuses creates an opportunity to capture representative data within these populations. However, the use of one's personal smartphone for health is based on self-selection and inherently prone to bias, which may be amplified over time with losses to follow-up occurring in longitudinal studies. In situations requiring representativeness, such as ILI rate estimation or characterization of vaccination practices, this limitation must be carefully considered during study design and implementation and in evaluation of data. In alternate situations, such as outbreak detection, representativeness of the sample is less vital, and smartphone approaches may thrive. A second notable strength of the smartphone-based approach to data collection is the ability to collect information in near-real time. The ability to capture

cues to action while salient and to detect outbreaks earlier than previously possible, are valuable opportunities for research to advance.

In conclusion, it is recommended that a multifaceted approach be used to incorporate smartphone-based components into public health surveillance, research, and interventions. Future efforts may harness multiple data sources to create a model that incorporates traditional methods, Google and search-trends, emergency room and pharmacy usage data, with absenteeism records, as well as smartphone reporting. The potential for smartphone-captured data to provide a valuable supplement to existing measures is vast; the ability of these ubiquitous devices to capture and disseminate data in near-real time offers opportunity to enhance standards in public health practices. To achieve the best outcome as the field of mHealth continues to develop, in each situation, the capability and accessibility of the smartphone must be weighed against the type and quality of data needed for a specific public health goal. As demonstrated by the surveillance and research findings of this initiative, the mHealth approach provides opportunity to expand impact and understanding of, rather than replace traditional methods entirely.

References

- Abroms, L.C., Padmanabhan, N., Thaweethai, L., Phillips, T., 2011. iPhone apps for smoking cessation: a content analysis. *Am. J. Prev. Med.* 40, 279–285.
doi:10.1016/j.amepre.2010.10.032
- Ambrose, C.S., Levin, M.J., Belshe, R.B., 2011. The relative efficacy of trivalent live attenuated and inactivated influenza vaccines in children and adults. *Influenza Other Respir. Viruses* 5, 67–75. doi:10.1111/j.1750-2659.2010.00183.x
- American College Health Association, 2012. *Healthy Campus 2020*.
- American Lung Association, 2010. *Influenza and Pneumonia. State of Lung Disease in Diverse Communities*.
- Bandura, A., 1994. Self-efficacy, in: *Encyclopedia of Human Behavior*. Academic Press, New York, pp. 71–81.
- Bastawrous, A., Armstrong, M.J., 2013. Mobile health use in low- and high-income countries: an overview of the peer-reviewed literature. *J. R. Soc. Med.* 106, 130–142. doi:10.1177/0141076812472620
- Bödeker, B., Walter, D., Reiter, S., Wichmann, O., 2014. Cross-sectional study on factors associated with influenza vaccine uptake and pertussis vaccination status among pregnant women in Germany. *Vaccine* 32, 4131–4139.
doi:10.1016/j.vaccine.2014.06.007

- Bomhold, C.R., 2013. Educational use of smart phone technology: A survey of mobile phone application use by undergraduate university students. *Program* 47, 424–436. doi:<http://dx.doi.org.ezproxy.library.wisc.edu/10.1108/PROG-01-2013-0003>
- Boschen, M.J., Casey, L.M., 2008. The use of mobile telephones as adjuncts to cognitive behavioral psychotherapy. *Prof. Psychol. Res. Pract.* 39, 546–552.
doi:[10.1037/0735-7028.39.5.546](https://doi.org/10.1037/0735-7028.39.5.546)
- Boulos, M.N., Wheeler, S., Tavares, C., Jones, R., 2011. How smartphones are changing the face of mobile and participatory healthcare: an overview, with example from eCAALYX. *Biomed. Eng. OnLine* 10, 24. doi:[10.1186/1475-925X-10-24](https://doi.org/10.1186/1475-925X-10-24)
- Breton, E.R., Fuemmeler, B.F., Abrams, L.C., 2011. Weight loss-there is an app for that! But does it adhere to evidence-informed practices? *Transl. Behav. Med.* 1, 523–529. doi:[10.1007/s13142-011-0076-5](https://doi.org/10.1007/s13142-011-0076-5)
- Bridges, C., Fukuda, K., Uyeki, T., Cox, N., Singleton, J., 2002. Prevention and control of influenza. Recommendations of the Advisory Committee on Immunization Practices (ACIP). *MMWR Recomm. Rep. Morb. Mortal. Wkly. Rep. Recomm. Rep. Cent. Dis. Control* 51, 1–31.
- Butler, D., 2013. When Google got flu wrong. *Nature* 494, 155–156.
doi:[10.1038/494155a](https://doi.org/10.1038/494155a)
- Carneiro, H.A., Mylonakis, E., 2009. Google Trends: A Web-Based Tool for Real-Time Surveillance of Disease Outbreaks. *Clin. Infect. Dis.* 49, 1557–1564.
doi:[10.1086/630200](https://doi.org/10.1086/630200)

- Carrat, F., Tachet, A., Rouzioux, C., Housset, B., Valleron, A.-J., 1999. Evaluation of Clinical Case Definitions of Influenza: Detailed Investigation of Patients During the 1995–1996 Epidemic in France. *Clin. Infect. Dis.* 28, 283–290. doi:10.1086/515117
- Centers for Disease Control and Prevention, 2011. Chapter 6: Influenza, in: *Manual for the Surveillance of Vaccine-Preventable Diseases*. Centers for Disease Control and Prevention, Atlanta, GA.
- Centers for Disease Control and Prevention, 2014a. *Influenza - Flu Basics*.
- Centers for Disease Control and Prevention, 2014b. *Overview of Influenza Surveillance in the United States*.
- Chomutare, T., Fernandez-Luque, L., Arsand, E., Hartvigsen, G., 2011. Features of mobile diabetes applications: review of the literature and analysis of current applications compared against evidence-based guidelines. *J. Med. Internet Res.* 13, e65. doi:10.2196/jmir.1874
- Coe, A.B., Gatewood, S.B.S., Moczygamba, L.R., Goode, J.-V., “Kelly” R., Beckner, J.O., 2012. The use of the health belief model to assess predictors of intent to receive the novel (2009) H1N1 influenza vaccine. *Innov. Pharm.* 3, 1–11.
- Cook, S., Conrad, C., Fowlkes, A.L., Mohebbi, M.H., 2011. Assessing Google Flu Trends Performance in the United States during the 2009 Influenza Virus A (H1N1) Pandemic. *PLoS ONE* 6, e23610. doi:10.1371/journal.pone.0023610

- Cowan, L.T., Van Wagenen, S.A., Brown, B.A., Hedin, R.J., Seino-Stephan, Y., Hall, P.C., West, J.H., 2013. Apps of steel: are exercise apps providing consumers with realistic expectations?: a content analysis of exercise apps for presence of behavior change theory. *Health Educ. Behav. Off. Publ. Soc. Public Health Educ.* 40, 133–139. doi:10.1177/1090198112452126
- Dailey, L., Watkins, R.E., Plant, A.J., 2007. Timeliness of Data Sources Used for Influenza Surveillance. *J. Am. Med. Inform. Assoc.* 14, 626–631. doi:10.1197/jamia.M2328
- Davidhizar, R., 1983. Critique of the health-belief model. *J. Adv. Nurs.* 8, 467–472.
- Deeks, A., Lombard, C., Michelmore, J., Teede, H., 2009. The effects of gender and age on health related behaviors. *BMC Public Health* 9, 213. doi:10.1186/1471-2458-9-213
- Dennison, L., Morrison, L., Conway, G., Yardley, L., 2013. Opportunities and Challenges for Smartphone Applications in Supporting Health Behavior change: Qualitative Study. *J. Med. Internet Res.* 15, e86. doi:10.2196/jmir.2583
- Eysenbach, G., 2006. Infodemiology: tracking flu-related searches on the web for syndromic surveillance. *AMIA Annu. Symp. Proc. AMIA Symp. AMIA Symp.* 244–248.
- Fishbein, M., Ajzen, I., 1972. Attitudes and normative beliefs as factors influencing behavioral intentions. *J. Pers. Soc. Psychol.* 21, 1–9.

- Garske, T., Legrand, J., Donnelly, C.A., Ward, H., Cauchemez, S., Fraser, C., Ferguson, N.M., Ghani, A.C., 2009. Assessing the severity of the novel influenza A/H1N1 pandemic. *BMJ* 339, b2840–b2840. doi:10.1136/bmj.b2840
- Gavin, P.J., Thomson Jr., R.B., 2003. Review of Rapid Diagnostic Tests for Influenza. *Clin. Appl. Immunol. Rev.* 4, 151–172.
- Ginsberg, J., Mohebbi, M.H., Patel, R.S., Brammer, L., Smolinski, M.S., Brilliant, L., 2009. Detecting influenza epidemics using search engine query data. *Nature* 457, 1012–1014. doi:10.1038/nature07634
- Google.org, 2008. Google Flu Trends.
- Green, M.S., 2000. Compliance with influenza vaccination and the health belief model. *Isr. Med. Assoc. J. IMAJ* 2, 912–913.
- Grohskopf, L., Olsen, S., Sokolow, L., Bresee, J., Cox, N., Broder, K., Karron, R., Walter, E., 2014. Prevention and Control of Seasonal Influenza with Vaccines: Recommendations of the Advisory Committee on Immunization Practices (ACIP). *MMWR Recomm. Rep. Morb. Mortal. Wkly. Rep. Recomm. Rep. Cent. Dis. Control* 63, 691–697.
- Hamilton, J.G., 1995. Needle phobia: a neglected diagnosis. *J. Fam. Pract.* 169.
- Hanley, M., Becker, M., 2012. A Multi-Year Analysis of College Student Cell Phone Usage and Advertising Acceptance. *Proc. Am. Acad. Advert. Conf.*

- Heffernan, R., Mostashari, F., Das, D., Karpati, A., Kulldorff, M., Weiss, D., 2004. Syndromic Surveillance in Public Health Practice, New York City. *Emerg. Infect. Dis.* 10, 858–864. doi:10.3201/eid1005.030646
- Janz, N.K., Becker, M.H., 1984. The Health Belief Model: a decade later. *Health Educ. Q.* 11, 1–47.
- Jenkins, K., 2014. II. Needle phobia: a psychological perspective. *Br. J. Anaesth.* 113, 4–6. doi:10.1093/bja/aeu013
- Kasl, S.V., Cobb, S., 1966. Health behavior, illness behavior, and sick role behavior. I. Health and illness behavior. *Arch. Environ. Health* 12, 246–266.
- Klepser, M.E., 2014. Socioeconomic Impact of Seasonal (Epidemic) Influenza and the Role of Over-the-Counter Medicines. *Drugs* 74, 1467–1479. doi:10.1007/s40265-014-0245-1
- Larson, E.B., Bergman, J., Heidrich, F., Alvin, B.L., Schneeweiss, R., 1982. Do Postcard Reminders Improve Influenza Vaccination Compliance?: A Prospective Trial of Different Postcard “Cues.” *Med. Care* 20, 639–648.
- Lazer, D., Kennedy, R., King, G., Vespignani, A., 2014. The Parable of Google Flu: Traps in Big Data Analysis. *Science* 343, 1203–1205. doi:10.1126/science.1248506

- Magruder, S.F., 2003. Evaluation of Over-the-Counter Pharmaceutical Sales As a Possible Early Warning Indicator of Human Disease. *Johns Hopkins APL Tech. Dig.* 24, 349–353.
- Montano, D.E., 1986. Predicting and understanding influenza vaccination behavior. Alternatives to the health belief model. *Med. Care* 24, 438–453.
- Monto, A.S., Ohmit, S.E., Petrie, J.G., Johnson, E., Truscon, R., Teich, E., Rotthoff, J., Boulton, M., Victor, J.C., 2009. Comparative efficacy of inactivated and live attenuated influenza vaccines. *N. Engl. J. Med.* 361, 1260–1267.
doi:10.1056/NEJMoa0808652
- Naleway, A.L., Henkle, E.M., Ball, S., Bozeman, S., Gaglani, M.J., Kennedy, E.D., Thompson, M.G., 2014. Barriers and facilitators to influenza vaccination and vaccine coverage in a cohort of health care personnel. *Am. J. Infect. Control* 42, 371–375. doi:10.1016/j.ajic.2013.11.003
- Nichol, K.L., D’Heilly, S., Ehlinger, E., 2005. Colds and influenza-like illnesses in university students: impact on health, academic and work performance, and health care use. *Clin. Infect. Dis. Off. Publ. Infect. Dis. Soc. Am.* 40, 1263–1270.
doi:10.1086/429237
- Nichol, K.L., D’Heilly, S., Ehlinger, E.P., 2008. Influenza vaccination among college and university students: impact on influenzalike illness, health care use, and impaired school performance. *Arch. Pediatr. Adolesc. Med.* 162, 1113–1118.
doi:10.1001/archpedi.162.12.1113

- Ohmit, S.E., Victor, J.C., Rotthoff, J.R., Teich, E.R., Truscon, R.K., Baum, L.L., Rangarajan, B., Newton, D.W., Boulton, M.L., Monto, A.S., 2006. Prevention of antigenically drifted influenza by inactivated and live attenuated vaccines. *N. Engl. J. Med.* 355, 2513–2522. doi:10.1056/NEJMoa061850
- Ohmit, S.E., Victor, J.C., Teich, E.R., Truscon, R.K., Rotthoff, J.R., Newton, D.W., Campbell, S.A., Boulton, M.L., Monto, A.S., 2008. Prevention of Symptomatic Seasonal Influenza in 2005-2006 by Inactivated and Live Attenuated Vaccines. *J. Infect. Dis.* 198, 312–317. doi:10.1086/589885
- Olson, D.R., Konty, K.J., Paladini, M., Viboud, C., Simonsen, L., 2013. Reassessing Google Flu Trends Data for Detection of Seasonal and Pandemic Influenza: A Comparative Epidemiological Study at Three Geographic Scales. *PLoS Comput Biol* 9, e1003256. doi:10.1371/journal.pcbi.1003256
- Ortiz, J.R., Zhou, H., Shay, D.K., Neuzil, K.M., Fowlkes, A.L., Goss, C.H., 2011. Monitoring Influenza Activity in the United States: A Comparison of Traditional Surveillance Systems with Google Flu Trends. *PLoS ONE* 6. doi:10.1371/journal.pone.0018687
- Patrick, K., Griswold, W.G., Raab, F., Intille, S.S., 2008. Health and the mobile phone. *Am. J. Prev. Med.* 35, 177–181. doi:10.1016/j.amepre.2008.05.001
- Patwardhan, A., Bilkovski, R., 2012. Comparison: Flu Prescription Sales Data from a Retail Pharmacy in the US with Google Flu Trends and US ILINet (CDC) Data as Flu Activity Indicator. *PLoS ONE* 7. doi:10.1371/journal.pone.0043611

- Plans-Rubió, P., 2012. The vaccination coverage required to establish herd immunity against influenza viruses. *Prev. Med.* 55, 72–77.
doi:10.1016/j.ypmed.2012.02.015
- Pons, V.G., Canter, J., Dolin, R., 1980. Influenza a/Ussr/77 (h1n1) on a University Campus. *Am. J. Epidemiol.* 111, 23–30.
- Ramsey, M.A., Marczinski, C.A., 2011. College Students' Perceptions of H1N1 Flu Risk and Attitudes toward Vaccination. *Vaccine* 29, 7599–7601.
doi:10.1016/j.vaccine.2011.07.130
- Rosenstock, I.M., 1974. Historical Origins of the Health Belief Model. *Health Educ. Behav.* 2, 328–335. doi:10.1177/109019817400200403
- Seale, H., Heywood, A.E., McLaws, M.-L., Ward, K.F., Lowbridge, C.P., Van, D., MacIntyre, C.R., 2010. Why do I need it? I am not at risk! Public perceptions towards the pandemic (H1N1) 2009 vaccine. *BMC Infect. Dis.* 10, 99.
doi:10.1186/1471-2334-10-99
- Setbon, M., Raude, J., 2010. Factors in vaccination intention against the pandemic influenza A/H1N1. *Eur. J. Public Health* 20, 490–494.
doi:10.1093/eurpub/ckq054
- Sobal, J., Loveland, F.C., 1982. Infectious disease in a total institution: a study of the influenza epidemic of 1978 on a college campus. *Public Health Rep.* 97, 66–72.

- Suess, T., Renschmidt, C., Schink, S.B., Schweiger, B., Nitsche, A., Schroeder, K., Doellinger, J., Milde, J., Haas, W., Koehler, I., Krause, G., Buchholz, U., 2012. The role of facemasks and hand hygiene in the prevention of influenza transmission in households: results from a cluster randomised trial; Berlin, Germany, 2009-2011. *BMC Infect. Dis.* 12, 26. doi:10.1186/1471-2334-12-26
- Thompson, W.W., Moore, M.R., Weintraub, E., Cheng, P.-Y., Jin, X., Bridges, C.B., Bresee, J.S., Shay, D.K., 2009. Estimating influenza-associated deaths in the United States. *Am. J. Public Health* 99 Suppl 2, S225–230. doi:10.2105/AJPH.2008.151944
- Treanor, J., 2004. Influenza Vaccine — Outmaneuvering Antigenic Shift and Drift. *N. Engl. J. Med.* 350, 218–220. doi:10.1056/NEJMp038238
- Uddin, M., Cherkowski, G.C., Liu, G., Zhang, J., Monto, A.S., Aiello, A.E., 2010. Demographic and socioeconomic determinants of influenza vaccination disparities among university students. *J. Epidemiol. Community Health* 64, 808–813. doi:10.1136/jech.2009.090852
- U.S. Department of Health and Human Services, 2010. *Healthy People 2020*.
- West, J.H., Hall, P.C., Hanson, C.L., Barnes, M.D., Giraud-Carrier, C., Barrett, J., 2012. There's an app for that: content analysis of paid health and fitness apps. *J. Med. Internet Res.* 14, e72. doi:10.2196/jmir.1977

World Health Organization, 2014. Influenza Fact Sheet, number 211 [WWW Document].

WHO. URL <http://www.who.int/mediacentre/factsheets/fs211/en/> (accessed 9.4.14).

World Health Organization, G.O. for eHealth, 2011. mHealth: New horizons for health through mobile technologies.

Zambon, M., 1999. Epidemiology and pathogenesis of influenza. *J. Antimicrob. Chemother.* 44, 3–9.

Appendices

Appendix A: OutSmart Flu app content

Appendix A.1: Orientation Survey

Hello Badger! Please take 2 minutes to get to know the app and learn about what to expect when you use it.

Within 24 hours, you will receive a "How Are You Feeling?" survey. On days you are not feeling well, report your symptoms to help spread the word, not the flu! When you're healthy, use the app to OutSmart Flu! (next page)

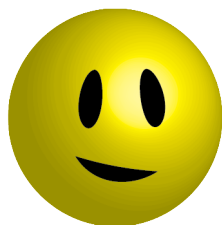
Symptom reports have 1 to 4 simple questions. You can try one out one on the next page. Afterward, you get some feedback. You can go back to a question anytime, but be aware that your previous answer may reset when you do. Your report is submitted and counted only after you click through the very last page.

Ready? (next page)

How are you feeling?

Healthy!

Sick.



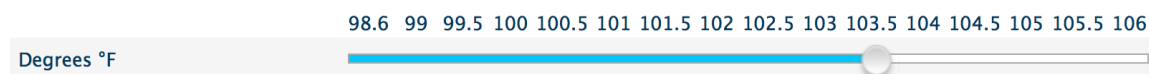
What symptoms are you experiencing? [select all that apply]

- Fever or feeling feverish (sweats or chills)
- Cough
- Sore throat
- Runny or stuffy nose
- Muscle or body aches
- Headache
- Fatigue (tiredness)
- Vomiting
- Diarrhea
- Other

Have you taken your temperature?

- Yes
- No

What is your highest measured temperature?



[Conditional symptom report responses in italics]

Your cold symptoms are more typical of an upper respiratory infection and not influenza-like illness.

(next page)

Your cold symptoms are more typical of an upper respiratory infection and not influenza-like illness.

(next page)

If you think you are running a fever, try to take your temperature. A fever, especially when associated with headache or vomiting, is potentially serious. Since Outsmart Flu does not provide medical diagnoses or healthcare, you should instead seek medical advice if your symptoms worsen or if you would ordinarily seek healthcare for symptoms such as the ones you reported. (next page)

Your cold symptoms are more typical of an upper respiratory infection and not influenza-like illness (ILI). If you had a measured temperature of 100°F or higher, then your symptoms would be more typical of ILI. Without a measured fever, your report will not be included in our counts of ILI reported to OutSmart Flu. (next page)

We are sorry that you are not feeling well. OutSmart Flu does not provide medical diagnoses or healthcare. If you would ordinarily seek healthcare for the symptoms you are experiencing, please do so. We hope you feel better soon! (next page)

A fever, especially when associated with headache or vomiting, is potentially serious. Since Outsmart Flu does not provide medical diagnoses or healthcare, you should instead seek medical advice if your symptoms worsen or if you would ordinarily seek healthcare for symptoms such as the ones you reported. (next page)

The symptoms you reported could be typical of an influenza-like illness (ILI). OutSmart Flu does not provide medical diagnoses or healthcare of any kind. If you would ordinarily seek healthcare for symptoms such as the ones you reported, please do so. Your symptom report will be included in OutSmart Flu's tracking of ILI on campus. (next page)

We are glad that you are feeling well. We hope you continue to Outsmart Flu! (next page)

Thank you for using the OutSmart Flu app and helping to protect our campus community! For the latest flu trends at UW-Madison, please visit www.outsmartflu.org. Be sure to visit the NEWS tab at the bottom of the app home page to get flu prevention tips and flu-related news at UW-Madison. (next to submit)

Great! You just completed a practice symptom report. You and your fellow OutSmart Flu users are helping to track influenza-like illness at UW-Madison. You can also use this app to stay on top of the latest flu counts and trends. Now, let's cover other parts of the app. (next page)

PROFILE Profile items help us see how representative OutSmart Flu users are of all UW students. That's important when tracking flu, so you'll earn 10 points for filling them out. (next page)

REWARDS On the Rewards page, monitor your OutSmart Flu points. There will be three \$500 raffles on campus (disclaimer: @wisc.edu addresses only). One point is one raffle ticket! You earn one point each time you complete the How Are You Feeling? survey. If you submit more than one report in a day, your point total will increase, but only one of those points will actually count as a raffle ticket :) (next page)

SURVEYS Here you will receive other surveys to earn more points:

Research Survey (available now: 50 points)

How are you preventing the flu? (15th & 30th of each month: 10 points each)

Follow-up Survey (spring semester: 50 points) (next page)

NEWS On occasion, we will send you a newsletter to update you on the OutSmart Flu initiative at UW-Madison. A recent one is on your Surveys page now. At the bottom of the home page, go to NEWS to get updated flu prevention tips and the latest flu-related news. Check back often! (next page)

INVITE FRIENDS You can share this app with your UW friends! Just hit the share button found in the upper right corner of the app. (next page)

As with any app, crashes do happen (usually a memory issue). These resolve when you reboot. If you're prompted to send us a crash report, please do so. This helps us improve and update the app. (next page)

LOST PASSWORD If you forget your OutSmart Flu password, send a blank email to passwords@outsmartflu.org from your @wisc.edu account (i.e., your OutSmart Flu login). Your password will be emailed to you within 24 hours. (next page)

Have an idea for OutSmart Flu? We want to hear them! Write us at ideas@outsmartflu.org. Want to get involved with the OutSmart Flu initiative at UW-Madison? Visit outsmartflu.org to learn how. Don't forget to connect with us on Facebook and Twitter! Welcome to the OutSmart Flu community! (next page to submit for 10 points)

Appendix A.2: Baseline Research Survey

This survey has three sections and takes 5-7 minutes to complete: (1) You and Your Smartphone; (2) Seasonal Flu; (3) Your Flu History. By completing this survey, you will earn 50 entries in the next \$500 raffle.

You and Your Smartphone (section 1 of 3)

What is your sex?

- Female
- Male

What is your date of birth?

Month Day Year

What is your class standing/UW affiliation?

- Freshman
- Sophomore
- Junior
- Senior
- Grad student
- Postdoctoral training
- Staff
- Faculty
- Other

What is your current housing?

- On-campus residence hall
- Near-campus apartment/house

- Off-campus/commuter
- Fraternity/Sorority house
- Other

Who are your living companions? [check all that apply]

- Student roommate(s)
- Non-student roommate(s)
- Parents/family
- None (live alone)
- Other

Do you have health insurance?

- Yes
- No
- I'm not sure

[If answered 'Yes' to having health insurance] **On whose health insurance plan you belong?**

- I am on my parent's or someone else's plan
- I have my own plan
- I'm not sure

Do you own any of the following devices? [check all that apply]

- Apple iPod touch
- Apple iPad
- Android tablet
- Tablet PC
- Other non-phone device capable of running apps

How much do you prioritize washing your hands in each of the following situations?

	Not a priority	Low priority	Medium priority	High priority	Essential
When they look dirty	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
After using my own bathroom	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
After being in a public restroom	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
After touching elevator buttons	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
After using a campus computer	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
After being at a crowded event	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
After coughing or sneezing	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
After interacting with someone who is sick	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Before eating food	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
After eating food	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Seasonal Flu (section 2 of 3)

How likely are each of the following situations to spread the flu?

	Very unlikely	Unlikely	Undecided	Likely	Very likely
Interacting with someone who is sick	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Being in a public restroom	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Touching elevator buttons	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Eating food that is expired or spoiled	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Coughing or sneezing	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Being at a crowded event	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Using a campus computer	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

How much do you agree/disagree with the following statements?

If I were to get the flu...

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
My symptoms would be serious	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I would miss class	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I would miss social activities	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Someone I know would get the flu because of me	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I would have to seek medical care	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I would be sick for more than a week	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

What symptoms characterize influenza (the flu)? [check all that apply]

- Cough
- Vomiting
- Rash
- Runny or stuffy nose
- Muscle or body aches
- Fever or feeling feverish
- Diarrhea
- Fatigue (tiredness)
- Dizziness
- Sore throat
- Itchy or red eyes
- Headache
- Other

How much do you agree/disagree with the following statements?

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I am at risk of getting the flu	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
The seasonal flu vaccine will protect me from the flu	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Hand hygiene will protect me from the flu	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
There are reasons why I cannot get the flu vaccine	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
It would be easy for me to get the flu vaccine	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
There are reasons why I can not wash my hands more frequently	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
It would be easy for me to wash my hands more frequently	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

To protect yourself from germs, for how many seconds should you wash your hands?

0	6	12	18	24	30	36	42	28	54	60
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Is alcohol rub an acceptable substitute for soap and water?

- Yes
- No
- I'm not sure

How much additional knowledge do you need to protect yourself from getting the flu?

	None	Little	Some	A lot
Additional knowledge needed	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Your Flu History (section 3 of 3)**Have you ever received the seasonal flu vaccine?**

- Yes
- No
- I'm not sure

[If answered 'Yes' to having ever received the seasonal vaccine] **During which of the past 4 flu seasons have you received the seasonal flu vaccine? [check all that apply]**

- 2010-11 school year
- 2011-12 school year
- 2012-13 school year
- 2013-14 school year (this year)

Where did you get this year's (2013-14) seasonal flu vaccine?

- Flu shot clinic held on campus
- University Health Services (Lucky Building; 333 East Campus Mall)
- Clinic/doctor's office (off-campus)
- Pharmacy
- Other _____

[If vaccination was not reported for this year (2013-14)] **Do you intend to get the seasonal flu vaccine this year (2013-14 school year)?**

- Yes
- No
- I'm not sure

[If vaccination was reported for this year (2103-14)] **How much influence did the following reasons have on your decision to get the vaccine this year?**

	No Influence	Some Influence	Strong Influence
Decrease likelihood of getting the flu	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Reduce transmission to classmate/coworkers/strangers	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Reduce transmission to relatives/friends	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Requirement for work or volunteering position	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Vaccine is safe and effective	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Easy and convenient/no reason not to	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Having a chronic condition/being at higher risk	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

In general, how much influence would the following reasons have on your decision to get the vaccine?

	No Influence	Some Influence	Strong Influence
Decrease likelihood of getting the flu	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Reduce transmission to classmate/coworkers/strangers	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Reduce transmission to relatives/friends	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Requirement for work or volunteering position	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Vaccine is safe and effective	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Easy and convenient/no reason not to	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Having a chronic condition/being at higher risk	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

[If answered 'No' to having intent to receive the vaccine this year (2013-14)] **How much influence did the following reasons have on your decision to not get the flu vaccine this year?**

	No influence	Some influence	Strong influence
Do not think myself at risk of getting the flu	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Lack of information about the vaccine	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Do not think the vaccine is effective	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Needle phobia	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Worried about the side effects	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inconvenient	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Vaccine might give me the flu	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Allergies to constituents of vaccine	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Prefer other ways to protect against the flu	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

In general, how much influence would the following reasons have on your decision to NOT get the flu vaccine?

	No influence	Some influence	Strong influence
Do not think myself at risk of getting the flu	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Lack of information about the vaccine	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Do not think the vaccine is effective	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Needle phobia	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Worried about the side effects	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inconvenient	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Vaccine might give me the flu	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Allergies to constituents of vaccine	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Prefer other ways to protect against the flu	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

This year, how much influence did the following sources of information have on your vaccination decision?

	No influence	Some influence	Strong influence
University Health Services recommendations	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Centers for Disease Control and Prevention (CDC) guidelines	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Media	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Peers	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Family	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Past experience	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other source of information	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

In general, how much influence do the following sources of information have on your vaccination decision

	No influence	Some influence	Strong influence
University Health Services recommendations	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Centers for Disease Control and Prevention (CDC) guidelines	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Media	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Peers	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Family	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Past experience	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other source of information	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Do you intend to get the seasonal flu vaccine NEXT flu season (2014-15)?

- Yes
- No
- I'm not sure

Do you believe you have ever had the flu?

- Yes
- No
- I'm not sure

Have you had flu-like symptoms this school year?

- Yes
- No
- I'm not sure

Do you know anyone who may have ever had the flu?

- Yes
- No
- I'm not sure

Anything else you would like to share?

Thank you for completing this survey! (next page to submit for 50 points)

Appendix A.3: Follow-up Research Survey

This survey has three sections and takes 5 minutes to complete: (1) You and OutSmart Flu; (2) Seasonal Flu; and (3) Your Flu History. By completing this survey, you will earn 50 entries in the next \$500 raffle.

You and OutSmart Flu (section 1 of 3)

What is your sex?

- Female
- Male
- Prefer not to answer

What is your current housing?

- On-campus residence hall
- Near-campus apartment/house
- Off-campus/commuter
- Fraternity/Sorority house
- Other

Who are your living companions? [check all that apply]

- Student roommate(s)
- Non-student roommate(s)
- Parents/family
- None (live alone)
- Other

How much do you prioritize washing your hands in each of the following situations?

	Not a priority	Low priority	Medium priority	High priority	Essential
When they look dirty	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
After using my own bathroom	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
After being in a public restroom	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
After touching elevator buttons	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
After using a campus computer	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
After being at a crowded event	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
After coughing or sneezing	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
After interacting with someone who is sick	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Before eating food	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
After eating food	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

How did you learn about the OutSmart Flu initiative? [check all that apply]

- Classroom presentation
- Campus fliers & signage
- Friend/ acquaintance
- Email
- Facebook/Twitter
- News
- Other

How much do you agree with the following statement?

OutSmart Flu has changed my opinions and/or knowledge about flu.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

What motivated you to use *OutSmart Flu* this year? [check all that apply]

- Facebook & Twitter updates
- Participating in research
- app newsfeed with flu prevention tips
- \$500 raffles
- Campus flu trends updates following symptom report
- Periodic newsletters
- OutSmart Flu* team member presentation
- I didn't use OutSmart Flu much this year
- Other

Do you plan to participate in the *OutSmart Flu* initiative again next year?

- Yes
- No
- I'm leaving campus
- I'm not sure

Did you share any of the following *OutSmart Flu* updates with friends or acquaintances? [check all that apply]

- Campus ILI activity updates
- Flu prevention tips
- Campus flu shot clinic details
- Information on how to join the study

Did you invite any of your friends/ acquaintances to join OutSmart Flu?

- Yes
- No
- I'm not sure

Seasonal Flu (section 2 of 3)

How likely are each of the following situations to spread the flu?

	Very unlikely	Unlikely	Undecided	Likely	Very likely
Interacting with someone who is sick	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Being in a public restroom	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Touching elevator buttons	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Eating food that is expired or spoiled	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Coughing or sneezing	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Being at a crowded event	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Using a campus computer	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

How much do you agree/disagree with the following statements?

If I were to get the flu....

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
My symptoms would be serious	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I would miss class	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I would miss social activities	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Someone I know would get the flu because of me	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I would have to seek medical care	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I would be sick for more than a week	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

What symptoms characterize influenza (the flu)? [check all that apply]

- Cough
- Vomiting
- Rash
- Runny or stuffy nose
- Muscle or body aches
- Fever or feeling feverish
- Diarrhea
- Fatigue (tiredness)
- Dizziness
- Sore throat
- Itchy or red eyes
- Headache
- Other

How much do you agree/disagree with the following statements?

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I am at risk of getting the flu	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
The seasonal flu vaccine will protect me from the flu	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Hand hygiene will protect me from the flu	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
There are reasons why I cannot get the flu vaccine	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
It would be easy for me to get the flu vaccine	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
There are reasons why I can not wash my hands more frequently	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
It would be easy for me to wash my hands more frequently	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

To protect yourself from germs, for how many seconds should you wash your hands?

0	6	12	18	24	30	36	42	48	54	60
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Is alcohol rub an acceptable substitute for soap and water?

- Yes
- No
- I'm not sure

How much additional knowledge do you need to protect yourself from getting the flu?

	None	Little	Some	A lot
Additional knowledge needed	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Your Flu History (section 3 of 3)

Did you receive the seasonal flu vaccine this school year (2013-14)?

- Yes
- No
- I'm not sure

[If answered 'Yes' to having received the seasonal vaccine this year (2013-14)] **Where did you get this year's (2013-14) seasonal flu vaccine?**

- Flu shot clinic held on campus
- University Health Services (Lucky Building; 333 East Campus Mall)
- Clinic/doctor's office (off-campus)
- Pharmacy
- Other _____

[If answered 'Yes' to having received the seasonal vaccine this year (2013-14)] **How much influence did the following reasons have on your decision to get the vaccine this year?**

	No Influence	Some Influence	Strong Influence
Decrease likelihood of getting the flu	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Reduce transmission to classmate/coworkers/strangers	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Reduce transmission to relatives/friends	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Requirement for work or volunteering position	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Vaccine is safe and effective	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Easy and convenient/no reason not to	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Having a chronic condition/being at higher risk	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

[If answered 'No' to having received the seasonal vaccine this year (2013-14)] **How much influence did the following reasons have on your decision to not get the flu vaccine this year?**

	No influence	Some influence	Strong influence
Do not think myself at risk of getting the flu	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Lack of information about the vaccine	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Do not think the vaccine is effective	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Needle phobia	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Worried about the side effects	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inconvenient	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Vaccine might give me the flu	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Allergies to constituents of vaccine	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Prefer other ways to protect against the flu	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

This year, how much influence did the following sources of information have on your vaccination decision?

	No influence	Some influence	Strong influence
University Health Services recommendations	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
University Health Services email reminders	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
OutSmart Flu newsfeed & flu prevention tips	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
OutSmart flu newsletters	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
OutSmart Flu campus flu trends reports	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Campus fliers & signage	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other source of information	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Compared to previous years, this year's flu season seemed...

- Much less severe
- Less severe
- Comparable
- More severe
- Much more severe

Do you intend to get the seasonal flu vaccine NEXT flu season (2014-15)?

- Yes
- No
- I'm not sure

Do you believe you have ever had the flu?

- Yes
- No
- I'm not sure

This past academic year (2013-2014), did you miss any classes due to flu-like symptoms?

- Yes
- No

This past academic year (2013-2014), did you miss any social activities due to flu-like symptoms?

- Yes
- No

This past academic year (2013-2014), did you seek health care for flu-like symptoms?

- Yes
- No

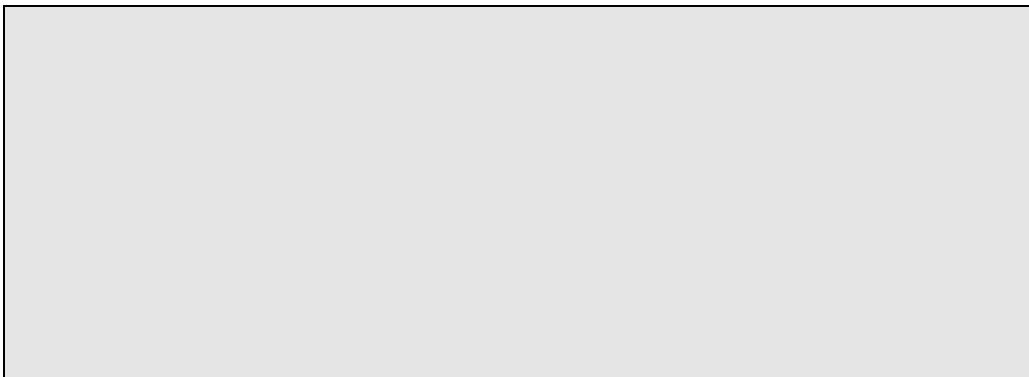
At any point during this school year (2013-14), did you experience a fever (temperature over 100°F) together with either a cough or a sore throat?

- Yes
- No
- I'm not sure

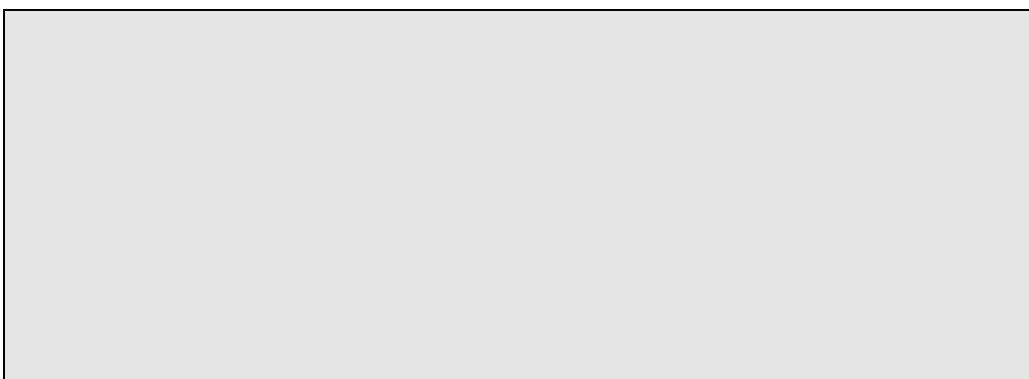
Do you know anyone else who has experienced a fever (temperature over 100°F) together with either a cough or a sore throat?

- Yes
- No
- I'm not sure

In what way can *OutSmart Flu* be improved for next year?



Anything else you would like to share?



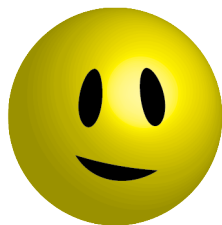
Thank you for completing this survey! (next page to submit for 50 points)

Appendix A.4: Symptom Report Survey

How are you feeling?

Healthy!

Sick.



What symptoms are you experiencing? [select all that apply]

- Fever or feeling feverish (sweats or chills)
- Cough
- Sore throat
- Runny or stuffy nose
- Muscle or body aches
- Headache
- Fatigue (tiredness)
- Vomiting
- Diarrhea
- Other

Have you taken your temperature?

- Yes
- No

What is your highest measured temperature?

98.6 99 99.5 100 100.5 101 101.5 102 102.5 103 103.5 104 104.5 105 105.5 106

Degrees °F 

[Conditional symptom report responses in italics]

Your cold symptoms are more typical of an upper respiratory infection and not influenza-like illness.

(next page)

Your cold symptoms are more typical of an upper respiratory infection and not influenza-like illness.

(next page)

If you think you are running a fever, try to take your temperature. A fever, especially when associated with headache or vomiting, is potentially serious. Since Outsmart Flu does not provide medical diagnoses or healthcare, you should instead seek medical advice if your symptoms worsen or if you would ordinarily seek healthcare for symptoms such as the ones you reported. (next page)

Your cold symptoms are more typical of an upper respiratory infection and not influenza-like illness (ILI).

If you had a measured temperature of 100°F or higher, then your symptoms would be more typical of ILI.

Without a measured fever, your report will not be included in our counts of ILI reported to OutSmart Flu.

(next page)

We are sorry that you are not feeling well. OutSmart Flu does not provide medical diagnoses or healthcare. If you would ordinarily seek healthcare for the symptoms you are experiencing, please do so. We hope you feel better soon! (next page)

A fever, especially when associated with headache or vomiting, is potentially serious. Since Outsmart Flu does not provide medical diagnoses or healthcare, you should instead seek medical advice if your symptoms worsen or if you would ordinarily seek healthcare for symptoms such as the ones you reported. (next page)

The symptoms you reported could be typical of an influenza-like illness (ILI). OutSmart Flu does not provide medical diagnoses or healthcare of any kind. If you would ordinarily seek healthcare for symptoms such as the ones you reported, please do so. Your symptom report will be included in OutSmart Flu's tracking of ILI on campus. (next page)

We are glad that you are feeling well. We hope you continue to Outsmart Flu! (next page)

Thank you for using the OutSmart Flu app and helping to protect our campus community! In the past 7 days, XX OutSmart Flu users reported symptoms consistent with influenza-like illness (ILI). As a comparison, XX% of students seeking healthcare at University Health Services have symptoms consistent with ILI. Be sure to visit "News" at the bottom of the app home page to get flu prevention tips and flu-related news at UW-Madison. Thank you for protecting the campus community. (next page to submit)

Appendix A.5: Flu Prevention Survey

Take a minute to share your flu prevention strategies.

Think about your typical routine to prevent getting or spreading the flu. Please indicate whether your behaviors have changed in the last two weeks compared to your typical routine.

	Decreased	No change	Increased
Your effort to wash your hands thoroughly	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Your effort to use alcohol rub	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Your effort to get enough sleep	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Your effort to avoid crowded places	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Your effort to cover your cough or sneeze	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Please share any other strategies you use to prevent getting the flu.

Regarding the 2013-14 seasonal flu vaccine...

- I do not intend to get the flu vaccine this year
- I am not sure if I will get the flu vaccine this year
- I intend to get the flu vaccine this year
- I got this year's flu vaccine in the last two weeks
- I got this year's flu vaccine more than two weeks ago

[If 2013-14 vaccination was reported] **Where did you get the 2013-14 seasonal flu vaccine?**

- Flu shot clinic held on campus
- University Health Services (Lucky Building; 333 East Campus Mall)
- Clinic/doctor's office (off-campus)
- Pharmacy
- Other _____

[If 2013-14 vaccination was reported as being received during the past two weeks] **What happened in the past two weeks to prompt you to get the 2013-14 flu vaccine?**

Thank you for sharing your flu prevention strategies. Check the OutSmart Flu news feed to learn about flu prevention and flu-related news on campus. (next page to submit for 10 points)

Appendix B: App Evaluation

Appendix B.1: Campus-wide App Evaluation Survey

Section (1/4) OutSmart Flu

OutSmart Flu is an initiative at UW Madison that uses a smartphone app to crowd-source surveillance of flu symptoms on campus. The app is used to report any flu-like symptoms, and get flu prevention tips. The symptom reports are then compiled and current flu activity on campus can be viewed on your smartphone.

OutSmart Flu aims to detect flu epidemics early to help members of our campus community take action to protect themselves and others from getting sick.



The poster features the University of Wisconsin-Madison logo at the top left. The main text reads "Use your smartphone for social action." followed by "OutSmart Flu" in large, bold letters. Below this, it says "Available on the App Store" and "Available on Google play". The central text lists: "YOU report how you are feeling", "YOU track flu cases on campus", and "YOU protect your health and other's". At the bottom, it says "visit outsmartflu.org to learn more". A QR code is located at the bottom center. To the right of the QR code are social media icons for "Follow us on Twitter" and "Like us on Facebook". In the bottom left corner, a red banner says "\$500 raffles with chances to win just for using the app!".

WISCONSIN
UNIVERSITY OF WISCONSIN - MADISON

Use your smartphone
for social action.

OutSmart Flu

Available on the
App Store

Available on
Google play

YOU report how you are feeling
YOU track flu cases on campus
YOU protect your health and other's

visit outsmartflu.org to learn more

\$500
raffles with
chances to win
just for using the app!

Follow us on
Twitter

Like us on
Facebook

We would like to know your familiarity with *OutSmart Flu*. During this past academic year (Fall '13 – Spring '14) did you...

	Yes	No	I'm not sure
hear about <i>OutSmart Flu</i> (prior to this survey)?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
download the <i>OutSmart Flu</i> app (from iTunes or GooglePlay)?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
log-in and use the <i>OutSmart Flu</i> app?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
see the above poster on campus?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
know anyone who used the <i>OutSmart Flu</i> app?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

The *OutSmart Flu* app provided users with updates about current campus levels of influenza-like illness (ILI), and also tips for flu prevention. Did anyone enrolled in the *OutSmart Flu* study share any of the following *OutSmart Flu* information with you? [check all that apply]

- Campus ILI activity updates
- Flu prevention tips
- Campus flu shot clinic details
- Information on how to join the study
- Other information
- I'm not sure
- No, I did not have *OutSmart Flu* information shared with me.

[If download and use of the *OutSmart Flu* app was reported] Did you share any of the following *OutSmart Flu* updates with friends or classmates on campus (in person, over SMS, on Facebook, on Twitter, etc.)? [check all that apply]

- Campus ILI activity updates
- Flu prevention tips
- Campus flu shot clinic details
- Information on how to join the study

How much do you agree/ disagree with the following statements?

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
My symptoms would be serious	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I would miss class	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I would miss social activities	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Someone I know would get influenza because of me	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I would have to seek medical care	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I would be sick for more than a week	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Compared to previous years, this year's flu season (Fall '13 – Spring '14) seemed...

- Much less severe
- Less severe
- Comparable
- More severe
- Much more severe

Section (3/4) Vaccination and Influenza History

Did you receive the seasonal flu vaccine? [check all that apply]

- This year (Fall '13 – Spring '14)
- Last year (Fall '12 – Spring '13)
- Previous years (Fall '11 – Spring '12 or earlier)
- Never

Where did you get the seasonal flu vaccine?

- University Health Services
- On-campus flu shot clinic
- Off-campus Primary Care Provider
- Other off-campus venue

Do you intend to get the seasonal flu vaccine during the NEXT flu season (Fall '14 – Spring '15)?

- Yes
- No
- I'm not sure

Do you believe you have ever had the flu?

- Yes
- No
- I'm not sure

This past academic year (Fall '13 – Spring '14), did you... [check all that apply]

- miss any classes due to flu-like symptoms?
- miss any social activities due to flu-like symptoms?
- seek health care for flu-like symptoms?

At any point during this academic year (Fall '13 – Spring '14), did *you* experience a fever (temperature over 100°F) together with either a cough or a sore throat?

- Yes
- No
- I'm not sure

At any point during this academic year (Fall '13 – Spring '14), did you know *anyone else* who experience a fever (temperature over 100°F) together with either a cough or a sore throat?

- Yes
- No
- I'm not sure

How much do you prioritize washing your hands in each of the following situations?

	Not a priority	Low priority	Medium priority	High priority	Essential
When they look dirty	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
After using my own bathroom	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
After being in a public restroom	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
After touching elevator buttons	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
After using a campus computer	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
After being at a crowded event	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
After coughing or sneezing	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
After interacting with someone who is sick	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Before eating food	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
After eating food	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Section (4/4) A Little Bit About You**Year in school**

- Freshman
- Sophomore
- Junior
- Senior

Year of birth

Month Day Year

Sex

- Female
- Male
- Prefer not to answer

Current housing?

- On-campus residence hall
- Near-campus apartment/house
- Off-campus/commuter
- Fraternity/Sorority house
- Other

Who are your living companions? [check all that apply]

- Student roommate(s)
- Non-student roommate(s)
- Parents/family
- Other
- I live alone

What is your major?

Do you have health insurance?

- Yes
- No
- I'm not sure

[If answered 'Yes' to having health insurance] **Health insurance coverage**

- Someone else's plan
- My own plan
- I'm not sure

Is your cell phone a smartphone?

- Yes
- No
- I don't have a cell phone

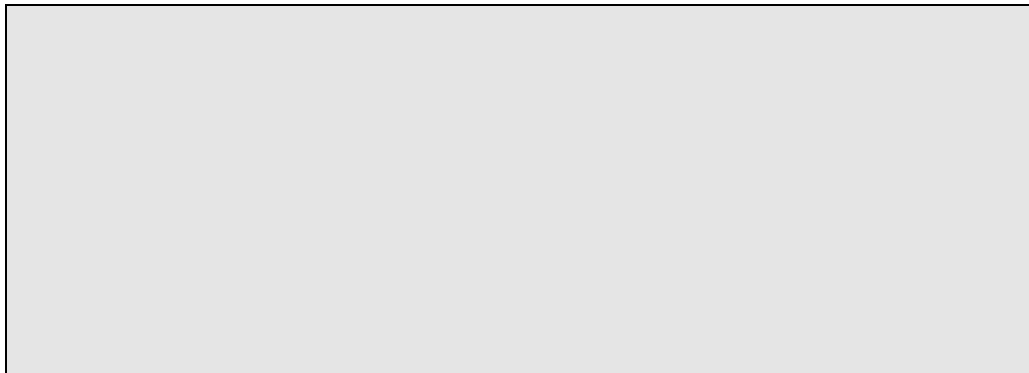
[If answered 'Yes' to having a smartphone] **What kind of smartphone(s) do you own? [check all that apply]**

- Apple iPhone
- Android-based (i.e. HTC One, Samsung Galaxy, Motorola DROID, etc.)
- Blackberry
- Windows Phone
- Other

Thank you for your time and consideration to complete this survey.

If you would like to be eligible to win one of our \$100 raffles or other cash prizes, please enter your @wisc.edu email address:

Is there anything else you would like to share?



Thank you for taking the time to complete our survey. Your participation is greatly appreciated.

Appendix C: Supplemental material for Chapter 4

Appendix C.1: Cronbach's alpha Coefficients for Measured Health Belief Model Domains as Measured at Baseline (N=589)

BASELINE						CB alpha	Item rest
Knowledge	Strongly agree	Agree	Neutral	Disagree	Strongly disagree		
Hand hygiene will protect me from the flu	228 (39.0)	280 (48.0)	54 (9.2)	17 (2.9)	6 (1.0)		
	None	Little	Some	A lot			
How much additional knowledge do you need to protect yourself from getting the flu?	117 (20.0)	249 (42.6)	202 (34.5)	17 (2.9)			
Benefits	Strongly agree	Agree	Neutral	Disagree	Strongly disagree		
The seasonal flu vaccine will protect me from the flu	154 (26.3)	238 (40.7)	99 (16.9)	66 (11.3)	28 (4.8)		
Barriers	Strongly agree	Agree	Neutral	Disagree	Strongly disagree		
There are reasons why I cannot get the flu vaccine	12 (2.1)	35 (6.0)	46 (7.9)	214 (36.6)	278 (47.5)		
It would be easy for me to get the flu vaccine	360 (61.5)	169 (29.0)	34 (5.8)	16 (2.7)	6 (1.0)		
SEVERITY	Strongly agree	Agree	Neutral	Disagree	Strongly disagree		
If I were to get the flu, my symptoms would be serious	85 (14.5)	198 (33.9)	167 (28.6)	124 (21.2)	11 (1.9)	0.686	0.607
If I were to get the flu, I would miss class	81 (13.9)	237 (40.5)	84 (14.4)	140 (23.9)	43 (7.4)		0.642
If I were to get the flu, I would miss social activities	189 (32.3)	296 (50.6)	47 (8.0)	45 (7.7)	8 (1.4)		0.645
If I were to get the flu, someone I know would get the	102 (17.4)	252 (43.1)	130 (22.2)	88 (15.0)	13 (2.2)		0.693

flu because of me							
If I were to get the flu, I would have to seek medical care	47 (8.0)	111 (19.0)	144 (24.6)	230 (39.3)	53 (9.1)		0.639
If I were to get the flu, I would be sick for more than a week	58 (9.9)	168 (28.7)	120 (20.5)	196 (33.5)	43 (7.4)		0.641

Susceptibility

How likely are each of the following situations to spread the flu?

	Very unlikely	Unlikely	Undecided	Likely	Very likely		
Interacting with someone who is sick	3 (0.5)	10 (1.7)	23 (4.0)	284 (48.8)	262 (45.02)	0.675	0.656
Being in a public restroom	27 (4.6)	122 (20.9)	102 (17.5)	244 (41.8)	89 (15.2)		0.610
Touching elevator buttons	23 (4.0)	98 (16.8)	107 (18.3)	262 (44.8)	95 (16.2)		0.576
Coughing or sneezing	3 (0.5)	10 (1.7)	44 (7.5)	276 (47.2)	252 (43.1)		0.666
Being at a crowded event	7 (1.2)	31 (5.3)	70 (12.0)	309 (53.0)	166 (28.5)		0.634
Using a campus computer	25 (4.3)	81 (13.9)	99 (17.0)	282 (48.3)	97 (16.6)		0.602
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree		
I am at risk of getting the flu	118 (20.2)	280 (47.9)	95 (16.2)	74 (12.7)	18 (3.1)		0.708

Prevention

How much do you prioritize washing your hands in each of the following situations?

	Not a priority	Low priority	Medium priority	High priority	Essential		
When they look dirty	5 (0.9)	6 (1.0)	54 (9.3)	197 (33.7)	322 (55.1)	0.844	0.846
After using my own bathroom	2 (0.3)	37 (6.4)	73 (12.5)	137 (23.5)	334 (57.3)		0.843
After being in a public restroom	0 (0.0)	7 (1.2)	33 (5.7)	107 (18.6)	429 (74.5)		0.842
After touching elevator buttons	148 (25.3)	177 (30.3)	193 (33.1)	50 (8.6)	16 (2.7)		0.815
After using a campus computer	136 (23.3)	164 (28.0)	166 (28.4)	76 (13.0)	43 (7.4)		0.815
After being at a crowded event	127 (21.7)	141 (24.1)	180 (30.8)	87 (14.9)	50 (8.6)		0.816
After coughing or sneezing	32 (5.5)	87 (14.8)	185 (31.6)	181 (30.9)	100 (17.1)		0.823
After interacting with someone who	12 (2.1)	40 (6.9)	121 (20.7)	183 (31.3)	228 (39.0)		0.825

is sick

Before eating food	47 (8.1)	102 (17.5)	184 (31.6)	156 (26.8)	94 (16.1)	0.824
After eating food	108 (18.5)	162 (27.7)	230 (39.4)	57 (9.8)	27 (4.6)	0.839

History	Yes	No	Unsure
Have you ever received the seasonal flu vaccine?	495 (84.6)	80 (13.7)	10 (1.7)
Do you believe you have ever had the flu?	437 (74.7)	100 (17.0)	52 (8.8)

Appendix D: Supplemental material for Chapter 5

Appendix D.1: OutSmart Flu (OSF) Demographics Compared at Baseline and Follow-up

Demographic	OSF population (N=787) N (%)	Baseline (N=585) N (%)	Follow up (N=188) N (%)	p value χ^2 test	
Sex (†/‡/§)					
Male	281 (35.7)	201 (34.4)	68 (36.2)	0.650	
Female	490 (62.3)	384 (65.6)	120 (63.8)		
Unreported	16 (2.0)				
Age (†)					
<=18	3 (0.4)	2 (0.3)	1 (0.5)	0.883 (F)	
19	63 (8.0)	58 (9.9)	15 (8.0)		
20	88 (11.2)	80 (13.7)	33 (17.6)		
21	112 (14.2)	102 (17.4)	29 (15.4)		
22	118 (15.0)	105 (18.0)	33 (17.6)		
23	72 (9.2)	67 (11.5)	21 (11.2)		
>=24	176 (22.4)	152 (26.0)	52 (27.1)		
Unreported	155 (19.7)	19 (3.3)	5 (2.7)		
School of study (†)					
					0.053
Ag & Life Sciences	135 (17.2)	116 (19.8)	46 (24.5)		
Education	24 (3.1)	20 (3.4)	7 (3.7)		
Engineering	35 (4.5)	29 (5.0)	14 (7.5)		
Human Ecology	13 (1.7)	11 (1.9)	3 (1.6)		
Letters & Science	141 (17.9)	122 (20.9)	36 (19.2)		
Undecided/ undeclared	25 (3.2)	22 (3.8)	12 (6.4)		
Nursing & Pharmacy	18 (2.3)	17 (3.0)	9 (4.8)		
Grad School	55 (7.0)	45 (7.7)	18 (9.6)		
N/A	24 (3.1)	21 (3.6)	8 (4.3)		
Unreported	285 (36.2)	155 (26.5)	27 (14.4)		
Class standing/ affiliation (‡)					
Freshman	-	95 (16.2)	32 (17.0)	0.075	
Sophomore	-	87 (14.9)	26 (13.8)		
Junior	-	118 (20.2)	34 (18.1)		
Senior	-	149 (25.5)	43 (22.9)		
Grad student/ Postdoc	-	98 (25.5)	40 (21.3)		
Faculty/ Staff	-	31 (5.3)	5 (2.7)		
Other	-	7 (1.2)	8 (4.3)		

Housing (profile-or at time of survey)				
On-campus res hall	384 (48.8)	134 (22.9)	45 (23.9)	0.629
Near-campus apt/house	137 (17.4)	325 (55.6)	95 (50.5)	
Off-campus/commuter	237 (30.1)	110 (18.8)	42 (22.3)	
Frat/Sorority house	10 (1.2)	12 (2.1)	4 (2.1)	
Other	-	4 (0.7)	2 (1.1)	
Unreported	282 (35.8)			
Living companions (at time of survey)				
Student roommates	-	414 (70.8)	127 (67.6)	0.946
Non-student roommates	-	62 (10.6)	19 (10.1)	
Parents/ family	-	56 (5.6)	17 (9.0)	
Other	-	17 (2.9)	7 (3.7)	
Living alone		73 (12.5)	26 (13.8)	
Reported 2013-14 vaccination (†/‡/§)				
Reported	389 (49.4)	370 (63.3)	148 (78.7)	<0.001
Unreported	398 (50.6)	215 (36.8)	40 (21.3)	

*NOTE: Demographics as reported in user profile (†), in baseline survey (‡), and in follow-up survey (§). Survey responses combined for immutable variables (i.e. sex, and 2013-14 vaccination).

(F) Fisher's exact test used

*Appendix D.2: Aggregate Weekly Surveillance Rate Estimates from University
SHC and OutSmart Flu (OSF) Data*

CDC Week	Total SHC clinic visits	SHC ILI rates	Total OSF ILI reports	OSF ILI rates	OSF 95% Wilson Confidence Interval
38	842	0.008	0	0.000	undefined
39	921	0.008	28	0.000	[0.121, 0.000]
40	861	0.017	77	0.013	[0.070, 0.002]
41	801	0.015	94	0.011	[0.058, 0.002]
42	845	0.006	113	0.027	[0.075, 0.009]
43	770	0.026	195	0.005	[0.028, 0.001]
44	893	0.016	255	0.012	[0.034, 0.004]
45	865	0.017	223	0.004	[0.025, 0.001]
46	813	0.021	206	0.015	[0.042, 0.005]
47	758	0.021	199	0.015	[0.043, 0.005]
48	380	0.013	175	0.011	[0.041, 0.003]
49	764	0.014	176	0.000	[0.021, 0.000]
50	776	0.039	176	0.011	[0.040, 0.003]
51	473	0.023	154	0.000	[0.024, 0.000]
52	39	0.026	120	0.008	[0.046, 0.001]
1	83	0.012	102	0.000	[0.036, 0.000]
2	156	0.032	94	0.021	[0.074, 0.006]
3	193	0.026	78	0.000	[0.047, 0.000]
4	539	0.017	82	0.000	[0.045, 0.000]
5	691	0.013	87	0.034	[0.097, 0.012]
6	717	0.011	92	0.000	[0.040, 0.000]
7	777	0.009	120	0.017	[0.059, 0.005]
8	776	0.023	114	0.018	[0.062, 0.005]
9	809	0.023	122	0.008	[0.045, 0.001]
10	825	0.022	146	0.007	[0.038, 0.001]
11	780	0.021	111	0.009	[0.049, 0.002]
12	172	0.017	42	0.024	[0.123, 0.004]
13	822	0.021	35	0.000	[0.099, 0.000]
14	890	0.019	22	0.000	[0.149, 0.000]
15	865	0.023	31	0.032	[0.162, 0.006]
16	845	0.026	14	0.000	[0.215, 0.000]
17	882	0.018	18	0.000	undefined
18	797	0.021	89	0.000	[0.041, 0.000]
19	857	0.026	16	0.000	[0.194, 0.000]
20	630	0.035	10	0.000	[0.278, 0.000]

Appendix E: Supplemental Material for Chapter 6

Appendix E.1: Interventional potential of the OutSmart Flu app

At follow-up, 121 (64%) participants indicated plans to participate in the *OutSmart Flu* initiative in the following year (2014-15) , and 85 (45.%) participants indicated that participation in *OutSmart Flu* had changed their opinions and/or knowledge about flu (Table 21).

Table 21. Participant-reported impact and acceptability of *OutSmart Flu*

Item	N (%)
<i>OutSmart Flu has changed my opinions and/or knowledge about flu.</i>	
Strongly disagree	9 (4.8)
Disagree	22 (11.6)
Neutral	72 (38.1)
Agree	78 (41.3)
Strongly agree	7 (3.7)
<i>Do you plan to participate in the OutSmart Flu initiative again next year?</i>	
Yes	121 (64.0)
No	2 (1.1)
I'm leaving campus	135 (8.5)
I'm not sure	129 (5.3)