What Motivates High School Students to Take Precautions against the Spread of Influenza? A Data Science Approach to Latent Modeling of Compliance with Preventative Practice

[*1a] William L. Romine, [2b]Tanvi Banerjee, [3c]William R. Folk, [4d]Lloyd H. Barrow

[a]Dept. of Biological Sciences, [b]Dept. of Computer Science and Engineering, Wright State University, 3640 Colonel Glenn Hwy, Dayton OH 45435

[c]Dept. of Biochemistry, [d]Dept. of Learning, Teaching, and Curriculum, University of Missouri, Columbia, MO 65211

[1]romine.william@gmail.com, [2]tanvi@knoesis.org, [3]folkw@missouri.edu, [4]barrowl@missouri.edu

Abstract – *This study focuses on a central question: What key behavioral factors influence high school students' compliance with preventative measures against the transmission of influenza? We use multi-level logistic regression to equate logit measures for eight precautions to students' latent compliance levels on a common scale. Using linear regression, we explore the efficacy of knowledge of influenza, affective perceptions about influenza and its prevention, prior illness, and gender in predicting compliance. Hand washing and respiratory etiquette are the easiest precautions for students, and hand sanitizer use and keeping the hands away from the face are the most difficult. Perceptions of barriers against taking precautions and sense of social responsibility had the greatest influence on compliance.*

Keywords: influenza mitigation, multilevel logistic regression, health informatics, quantitative analysis, decision support system

1 Introduction

In the United States, influenza imposes a heavy cost to our health and financial wellbeing, accounting for over 100,000 deaths and 1.7 million hospital stays over 10 influenza seasons (1999-2009) [1]. Influenza can result in medical costs of approximately $10 billion, lost earnings of $16 billion annually, and a total economic burden of $87 billion [2]. Given that approximately 10% of our school children contract influenza each year [3], influenza impedes education. Students missing school due to illness [4] results in reduced learning [5], free or reduced lunch benefit [4], parents missing work for childcare [6], and delinquency when children go unsupervised [7].

Both pharmaceutical (e.g. stockpiling vaccines and antivirals) and non-pharmaceutical options (e.g. quarantine and school closure) have been considered for managing severe influenza epidemics and pandemics [8, 9]. While these can be effective in reducing the spread of influenza, they can be socially intrusive and economically expensive [8, 9].

The motivation for this study comes from the hypothesis that educational or behavioral interventions focused on increasing compliance with preventative measures are an economical and effective way to reduce the spread of influenza. The central question of this study is: *What key cognitive and behavioral factors influence high school students' compliance with preventative measures against influenza transmission?* In addressing this question, we focus on two sub-questions: (1) what hierarchy exists in students' compliance with recommended precautions for preventing the spread of influenza, and (2) what is the efficacy of four variables: (1) students' knowledge of influenza, (2) affective perceptions of influenza and its prevention, (3) prior illness, and (4) gender in predicting students' compliance? We explore the relationship between these variables and compliance in a data driven approach that can improve targeted interventions supporting influenza management in schools.

2 Related Work

Multiple studies have suggested that cognitive, affective, and demographic factors may lead to compliance with measures to prevent the spread of influenza. However, a majority of these studies have targeted compliance with vaccination [10-14] and hand washing [14, 15] exclusively. Knowledge of influenza was found to increase vaccination rates in nurses [10, 11] and parents of school children [12]. A positive increase in vaccination rates in relation to perceived risk of influenza [13] and perceived complications of influenza [14] was found in university students and employees, and nurses, respectively. Ethnicity [14] and gender [13] were also found to impact compliance with vaccination. Barriers against compliance with vaccination include concerns over contracting the flu from vaccination, belief that vaccination is not effective, aversion to needles, and belief that influenza does not pose a significant health risk [10].

Findings regarding compliance with handwashing bear similarity to those for vaccination. Improved compliance with hand washing among hospital nurses was promoted by posters describing how infection is transmitted by the hands [15]. A positive relationship between knowledge of influenza and compliance with hand washing was also found in high school students [16]. Perceived barriers such as skin irritation, inconvenience, wearing gloves, and absent-mindedness were shown to impede compliance with hand washing across multiple populations [15-17]. Females were found to exhibit higher compliance with hand washing than males [17].

Studies addressing precautions against flu transmission as a holistic construct targeted high school students [16, 18] and the general public [19]. Using separate logistic regression models, these studies found that, along with vaccination and hand washing, perceived severity of influenza was a predictor for social distancing, and perceived efficacy was a positive predictor for all precautions. Other elements of hygiene such as respiratory etiquette and keeping hands away from the face were positively related to knowledge of influenza in high school students [17]. Perceived complications from influenza also played a positive role in students' decisions to stay home when sick and stay away from peers who were visibly sick [17].

While survey methods have been used in prior research of compliance with measures to prevent spread of influenza [17-19], we know of no research on measuring compliance with preventative behavior as a latent variable. Looking at multiple preventative measures hierarchically using a common scale, as opposed to looking at one precaution at a time, is essential in obtaining a more holistic understanding of how knowledge of influenza and affective perceptions influence compliance with preventative measures. Such analyses can help health education specialists target specific factors to improve student understanding and help reduce the transmission of influenza. In the next section, we describe our data-driven approach to develop a decision support system aimed at understanding and improving student compliance with influenza mitigation behaviors.

3 Experiments and Analysis

3.1 Conceptual Framework

Cognitive, affective, and demographic factors were related to compliance with behaviors to prevent influenza transmission using data described in [16, 18]. These variables were measured using the Student Influenza Survey described in our earlier work [18]. Cognition was qualified in terms of knowledge of influenza [18, 20]. Affective variables were derived from the Health Belief Model [21], which suggests that health behaviors are guided by perceptions of risk of contracting influenza, perceived severity of complications from influenza, barriers against taking preventative measures, and sense of social responsibility [21]. These variables were normalized to a scale of standard deviations centered at zero. Gender was the only demographic factor explored in this study given its documented importance [13]. Despite some literature pointing to the importance of ethnicity [14], the ethnicity distribution in our sample (described in Section 3.2) was not sufficiently diverse to warrant statistical exploration. Eight precautions (right side of Figure 1) were measured on an ordinal 1-5 scale, where a value of 1 indicates complete neglect of the precaution, and a value of 5 indicates frequent, accepted practice.

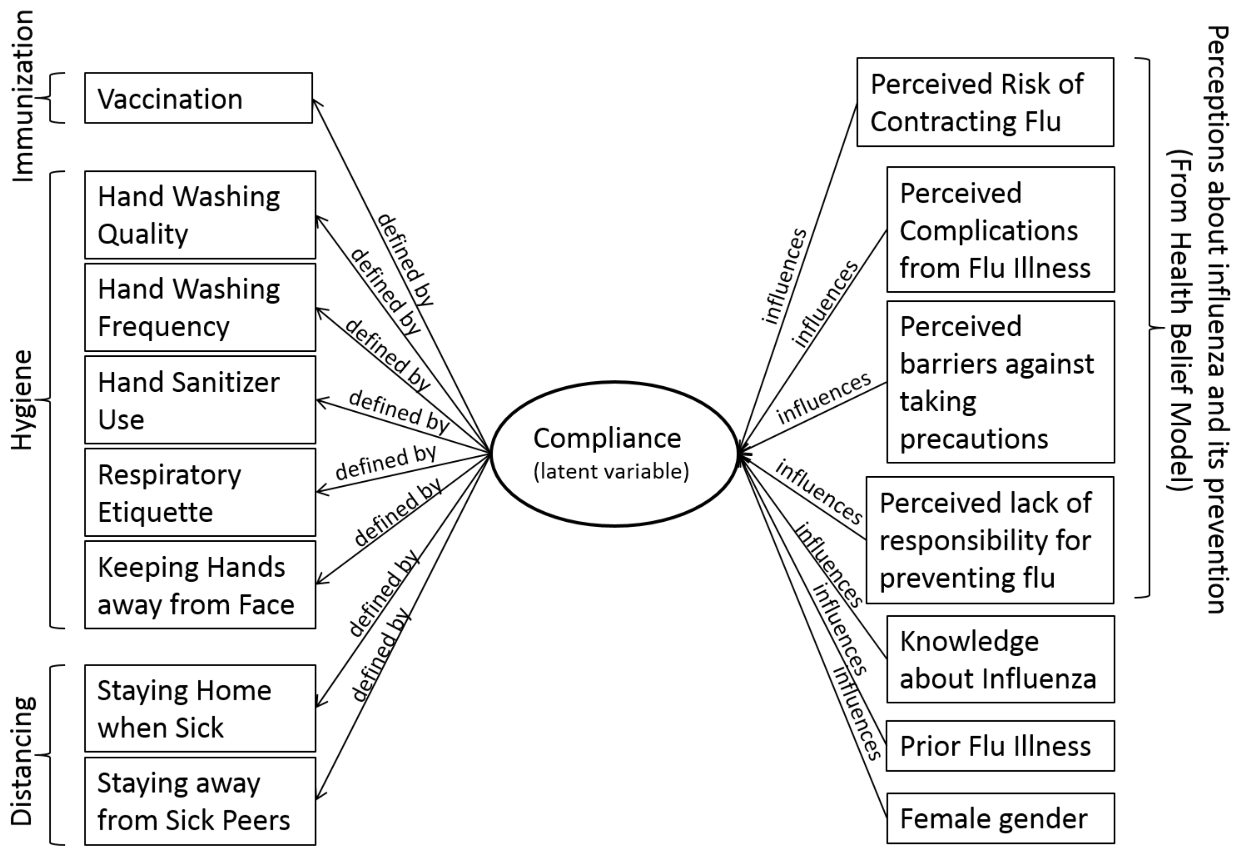

Figure 1. Conceptual framework of our decision system which models compliance with influenza prevention as a latent variable. Our latent variable of compliance is defined by immunization, five hygiene behaviors, and two distancing behaviors. We hypothesize that four perceptions of influenza derived from the Health Belief Model [21], knowledge about influenza [16, 18], gender [13], and prior flu illness influence high school students' compliance with measures to prevent the spread of influenza.

Middle (2, 3, and 4) levels represent a monotonic gradation between the lowest and highest levels. As an example, when asked about vaccination, the value 1 in the scale aligns with the students' report that they never get vaccinated for influenza. The value 5 indicates that the students get vaccinated against influenza every year. In the next subsection, we discuss our data collection process and the statistical methods used to understand the data.

3.2 Data Collection and Statistical Models

The Student Influenza Survey was administered to a sample of 410 students enrolled in grades 9-12 (median age of 16 years) from five school districts. Of the 375 students reporting their gender, 169 were male and 206 were female. A majority reported White ethnicity (n = 266). However, Black (n = 50), Asian (n = 27), and Hispanic (n = 22) ethnicities were also reported in the sample.

Multi-level logistic regression modeling using BIGSTEPS [23] was used to equate students' compliance with precautions and the difficulty of individual precautions on a common logit (log-odds) scale. This was specified as an ordinal random intercept model where students were modeled as the random factor and the eight precautions were treated as fixed factors. Important advantages of using multilevel logistic regression include: (1) ability to equate student compliance measures and precaution difficulty measures on a common logit scale; and (2) ability to obtain student compliance measures that are survey-independent and precaution difficulty measures that are student-independent [22]. Using linear regression, students' logit measures for compliance along the latent scale were equated to (1) knowledge of influenza, (2) perceived risk of contracting influenza, (3) perceived complications from the flu illness, (4) students' perceived barriers getting in the way of complying with precautions, (5) lack of perceived social responsibility (or inefficacy),

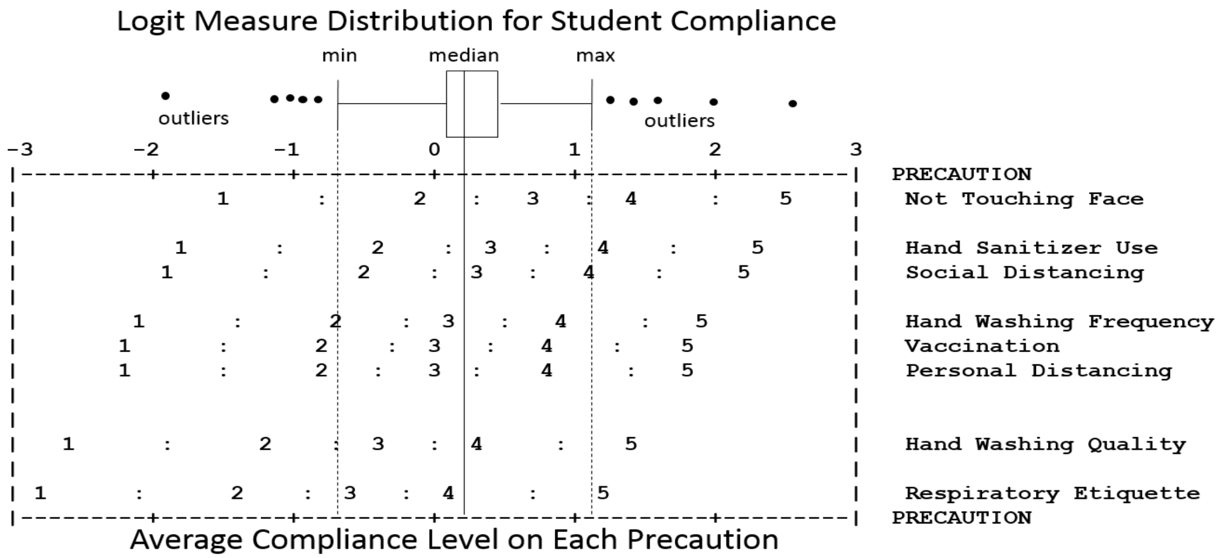

Figure 2. Expected average ordinal compliance level (1=lowest; 5=highest) on the eight precautions plotted against students' logit scale measures for the latent variable. On average, students at the median are expected to exhibit a compliance level between a 2 and a 3 for "not touching the face." The same students are expected to have an average compliance level just above a 4 for "respiratory etiquette." The Student Influenza Survey and detailed descriptions of response levels is available in [18].

(6) flu illness the prior year, and (7) gender. Statistical significance of these effects on compliance with precautions was evaluated at the 95% confidence level.

3.3 Formulating a Compliance Scale

The pattern of student responses for each precaution fit well with the multi-level ordinal random intercept logistic regression model, with normed chi-square values between 0.66 and 1.42. This illustrates the efficacy of the eight precautions in positioning students along a common latent compliance metric (Figures 1 and 2) [24]. Principal components analysis was implemented on the model residuals, revealing a first eigenvalue of 1.37 items of variance. This indicated that the systematic variance in the model was sufficient to explain the data [25], and that the remaining variance was random noise. Figure 2 displays the student measure distribution along the logit scale (the box-whisker plot at the top of Figure 2), and displays the average compliance level on each precaution that we would expect from students of a particular logit measure along the hierarchy of preventative behaviors. The behaviors are ranked in an increasing order such that those at the top of Figure 2 are the most difficult for students to comply with, and those at the bottom are easiest. As an example, respiratory etiquette and quality hand washing appear to garner the greatest compliance levels from students. Students at the median (the middle vertical line labeled "median" in Figure 2) are expected to exhibit behavior levels around 4, indicating that these students wash their hands for a duration with soap and water, and that they use a fabric or tissue in which to cough or sneeze (we encourage the reader to consult the Student Influenza Survey in [18] for additional qualitative details on the 5-level ordinal scale for the eight precautions). The students at the top of the scale (the right vertical line labeled "max" in Figure 2) approach a 5 level, indicating that they wash with soap and water for at least 30 seconds and use their sleeve or a tissue (which is then thrown away) when they cough or sneeze. As indicated by Figure 2, the following precautions at the top of the scale: keeping hands away from the face, and hand sanitizer use are the most difficult precautions for students to practice. Students at the median exhibit compliance levels below 3 on these behaviors indicating that they touch their eyes, nose, and mouth with their hands multiple times per day and use alcohol-based hand sanitizers (when available) around once per day. Students at the top of the scale have an expected level of 4 for these behaviors indicating that they touch their eyes, nose, and mouth only a few times within a 1-week time frame, and use hand sanitizers more than once daily. It is interesting that vaccination, which has perhaps received the greatest attention as a measure to prevent seasonal epidemics and pandemics in schools [26, 1], sits at the middle of the scale. Students in the middle of the latent compliance scale comply with vaccination at a 3 level, meaning that he/she has taken the vaccination before, but does not plan on taking it in the current flu season. Students at the top of the scale exceed a 4 level on average, indicating that they plan on receiving the vaccination during the current flu season. While it is encouraging that vaccination is not among the most difficult precautions for students to take, this finding shows that efforts are needed to make compliance with vaccination easier for high school students.

Other behaviors of moderate difficulty include frequent hand washing and distancing behaviors such as staying home when sick (personal distancing) and staying away from peers who are visibly sick (social distancing). Students in the middle of the compliance scale are expected to behave at a 3 level, indicating willingness to wash hands 3-4 times a day and keep distance from sick peers. These students, however, generally attend school if they consider their symptoms to be minor. Students at the top of the scale, however, behave at a 4 level on these precautions, indicating that they wash their hands 5-6 times per day and will request to the teacher that they be moved if a visibly sick student is sitting near them. These students indicate willingness to stay home when they are sick as long as they do not have an important school engagement such as an exam.

3.4 Factors Influencing Compliance

We now explore factors which influence students' latent compliance levels in our decision support model (right side of Figure 1). These factors include student knowledge of influenza, perceptions of influenza and its prevention, gender, and prior flu illness. The linear regression decision model (shown in Table 1) for the latent outcome of compliance was statistically significant ($F_{7,343} = 13.6$, $p << 0.001$, $r^2_{adj} = 0.20$) indicating that this models the data significantly better than simply calculating students' mean latent compliance level. The variables in the model collectively explain 20% of the variation in the latent variable indicating potential efficacy as a decision support model. Overwhelmingly the most significant predictors of compliance are students' perceptions of barriers against taking effective preventative behaviors and inefficacy (lack of perceived social responsibility for taking appropriate precautions against the spread of influenza).

Table 1. Predictors for high school students' positions along the latent scale for compliance with preventative measures against the spread of influenza.

Predictor	Coef.	SE	T	partial r^2
Risk	0.088	0.051	1.730	0.009
Complications	0.056	0.050	1.110	0.004
Barriers	-0.404	0.061	-6.640*	0.114
Inefficacy	-0.228	0.042	-5.390*	0.078
Flu Illness	0.001	0.060	0.020	0.000
Female	0.117	0.044	2.650*	0.020
Flu Knowledge	-0.041	0.037	-1.110	0.004
Intercept	0.076	0.043	1.780	0.009

*Significant at 95% confidence level

An example of perceived barriers includes the belief that the flu vaccination is harmful, ineffective, or difficult to obtain. Other examples include difficulty or unavailability of access to hand sanitizers, or belief that it is socially difficult to distance oneself from peers who are sick.

Indicators of inefficacy include the beliefs that: (1) one has no control over contracting influenza, (2) becoming sick will not affect schoolwork, and (3) taking precautions does not affect social relationships with friends and teachers. A one logit increase in perceived barriers and inefficacy leads to a decrease of 0.4 and 0.23 logits along the compliance scale (Figure 2), respectively. Taken together, a one logit increase in these factors could lead to over one half of a logit decrease in a student's latent compliance level. Further, a less responsible student who finds taking precautions difficult may be over one logit lower on the compliance scale than a more responsible student who takes precautions as part of his/her routine. This could make a difference of over one level (for example, a 3 level instead of a 4 level) along the ordinal scale for individual preventative behaviors (Figure 2).

The model also shows that females have an average level of compliance approximately 0.12 logits higher than males. While this difference is statistically significant, Figure 2 shows that gender is unlikely to make a major difference in students' individual preventative behaviors except in borderline cases. Although gender does not have the practical significance of perceived barriers or inefficacy, it nonetheless suggests that targeting of males could be one element of a successful behavioral intervention aiming to improve flu prevention in high school students.

4 Conclusion

We develop and implement a decision system that: (1) explains compliance with behaviors which mitigate spread of influenza as a continuous latent variable composed of eight accepted preventative practices, and (2) uses gender and two affective variables to predict students' levels of compliance. While measures like quarantine, mass vaccination campaigns, and school closure have been invoked in the context of severe seasonal epidemics and pandemics such as the relatively recent H1N1 Swine Flu pandemic [27], these measures can be expensive and difficult to implement for relatively frequently occurring diseases like influenza—behavioral interventions could serve as a supplement.

Our analyses suggest that it is feasible to develop behavioral interventions which encourage students to take precautionary measures such as immunization, hygiene, and distancing. From our model, we find that the most effective interventions should address the students' barriers in taking preventative measures. An effective program will educate them about the availability of the flu vaccine and resources for hygiene such as tissues and hand washing facilities. Students also should be made aware of the significance of taking preventative measures on a civic level—while people are generally aware that these behaviors can protect themselves against the flu, they are often unaware that efforts to take preventative measures also protect others [28].

Finally, our analysis demonstrates the importance of school policies in preventing the spread of influenza, and perhaps other viruses such as measles and zika, among students and school staff. Implementation of school vaccination programs would eliminate students' perception that the vaccine is expensive or unavailable. Installation of alcohol-based hand sanitizers would have a similar effect, making hand hygiene more accessible for students. Policies encouraging social and personal distancing may serve to mitigate outbreaks by reducing influenza transmission if infected students choose to stay home when they are sick. These may involve the decisions to: (1) not reward perfect attendance, especially during flu season; (2) encourage teachers to develop alternative assignments for students who miss class due to illness, and (3) not penalize students for missing class examinations, or providing opportunities to make up for missed examinations during the flu season.

Using a data driven approach to understand high school students' compliance with precautions against influenza transmission, our analysis suggests that schools have many options for improving practices to prevent the spread of infectious diseases like influenza. Schools which deliver effective educational programs and prevention-friendly policies will give students a sense of control over their own health and the health of their peers, and will likely reap the reward of reduced illness and absenteeism during the flu season. These benefits are likely to be transferable to other diseases which spread in a similar manner as influenza.

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