

The Effectiveness of a Cervical Cancer Vaccine

Adventures in Supercomputing Challenge

Final Report

April 7, 2004

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Executive Summary

A major breakthrough in modern science has led to the development of a vaccine that has the potential to eliminate or reduce cervical cancer. Though the problem of cervical cancer and the fatalities resulting from this cancer are not new ones, modern advance toward this vaccine to prevent infections with the virus that causes this type of cancer have brought closer public scrutiny and criticism regarding the vaccine and the properties of the vaccine. The use of this vaccine in teenage girls and young women resulted in immediate media attention and, thus, brought the problems of the vaccine to light. The company producing this vaccine, Merck Research Laboratories, has had to deflect the criticism away from them in order to further the research from their testing.

This project was originally designed as a way to model the effects of this vaccine, under real world circumstances, to determine if or if not this vaccine would be worth its cost and associated hassles (i.e. distribution or effectiveness) in the distant future. This model could be used with other vaccines to be developed in the future for preventing cervical cancer. Because the vaccine produced by Merck only focuses on two types of cervical cancer, we intended, in the beginning, to determine if the other types of the cancer would increase due to the decrease in these two types of cancer.

Introduction

The Issue

An estimated 471,000 new cases of cervical cancer are diagnosed each year. The American Cancer Society estimates that in 2003, about 12,000 cases of invasive cervical cancer will be diagnosed in the United States. Out of these 12,000 cases, roughly 4,100 women will die from this cancer. This makes the Human Papillomavirus that causes cervical cancer one of the leading causes of cancer death in the United States. Merck Research Laboratories is currently testing a vaccine for preventing cervical cancer caused by two types of the HPV, 16 and 18, and they expect to release the vaccine sometime in the year 2004- 2005. HPV 16 and 18 are the two most common causes of cervical cancer, and account for over 50% of the known cases of cervical cancer. Although there is a vaccine being tested, as we mentioned, it will only prevent cancer caused by two types of HPV. With the decrease in these two types, it may be possible that the other 60+ types of HPV will increase. Thus, there is a possibility that the vaccine would not be worthwhile until there are vaccines for all types of the virus. Other difficulties with the vaccine include, but are not limited to: the cost of the vaccine (i.e. would the vaccine be available to the poverty stricken areas where the cancer is most apparent), the reaction of the body to the vaccine (i.e. would some bodies reject the vaccine seeing it as a foreign substance), the distribution (i.e. would

those who could afford it know about the vaccine and take measures to ensure they receive it?). We selected this project to model these variables and others, based on individual behaviors, and to aid those who will be interested in this topic in the future.

The Project

Our project was to model the effectiveness of the vaccine against types HPV 16 and 18, in the real world, and simulate six different variables. To successfully model this we incorporated the six variables of: vaccine acceptance, the vaccine efficacy and effectiveness, the proportion of the population with high, medium, and low sexual activity, and the risks for the three levels of sexual activity.

Definition of Terms:

Vaccine acceptance included: what percent of the population takes the vaccine.

The vaccine efficacy is how the vaccine performs under ideal circumstances and effectiveness is how the vaccine performs under real- world circumstances. In our project we incorporated the percentage of the population who took the vaccine and saw positive effects as a measure of effectiveness. In preliminary tests done by Merck Research Laboratories, the vaccine proved to be 100% efficacious, so in our code we programmed it to be 100% efficacious as well.

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Those with a high level of sexual activity had a greater risk of obtaining the virus, and those with a low level of sexual activity had the lowest risk of obtaining the virus. Our first version of the code incorporated the percentage of the population who used a condom when they had sex. This behavior would have resulted in a lower risk of obtaining the virus. However, after faulty additional research, we “discovered” that condoms do not aid in preventing the spread of the virus because of the microscopic size of the virus (see background information). We came up with a second code, but discovered that this research was incorrect after talking with Dr. Williams, so we then incorporated the use of condoms in our program, switching back to the original code (see background information). We understand that our code would not pertain to all instances in which the virus is present, yet we do believe that our code is extremely relevant to many of the situations.

Background Information

Due to the topic of our project, our information came from a variety of sources: therefore, our information is widespread and it is possible to come to easy conclusions with it, due to the variety of information that comes together to make a whole.

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Region	No. of cases			Incidence						
	1985 (34)	1990 (35)	2000 (36)	CR**	ASRW**	Age specific incidence, y	15-44	45-54	55-64	65+
World	437,300	371,200	470,606	15.7	16.1		9.5	44.9	51.8	41.9
More developed	93,700	83,300	91,451	15.0	11.3		11.9	22.4	23.8	26.3
Less developed	343,600	287,900	379,153	15.8	18.7		9.0	53.6	65.0	53.8
Africa	51,500	52,500	67,078	17.1	27.3		11.0	71.5	100.5	95.4
Eastern	21,800	21,500	30,206	24.4	44.3		16.1	114.8	174.4	153.9
Middle	6,600	5,700	6,947	14.4	25.1		8.5	54.0	73.3	137.4
Northern	6,200	5,200	10,479	12.2	16.8		6.2	49.0	68.5	45.9
Southern	6,600	6,500	5,541	23.2	30.3		15.5	67.8	98.5	118.2
Western	10,300	13,600	13,903	12.5	20.3		9.5	57.4	70.6	60.3
America	68,000	74,800	92,136	22.0	21.0		15.1	55.2	57.8	55.0
Caribbean	3,000	5,000	6,670	34.8	35.8		17.7	82.7	102.1	155.6
Central	13,700	17,700	21,596	31.7	40.3		22.5	111.7	109.9	136.1
South	35,300	36,900	49,025	28.1	30.9		16.8	85.5	90.2	101.4
United States and Canada	16,000	15,200	14,845	9.5	7.9		9.0	15.4	16.8	14.2
Europe	67,000	58,200	64,928	17.2	13.0		14.1	26.3	26.5	28.1
Eastern	40,100	27,500	35,482	21.9	16.8		17.8	34.5	34.9	36.6
Northern	6,300	7,600	6,049	12.6	9.8		12.0	17.6	16.7	20.2
Southern	8,700	9,900	10,116	13.7	10.2		10.5	20.8	23.7	20.9
Western	11,900	13,200	13,282	14.2	10.4		11.3	20.5	19.6	25.1
Asia	249,000	183,400	245,670	13.6	14.9		7.2	44.0	52.8	39.6
Asia excluding China	170,800	158,700	212,297	18.0	21.1		10.3	63.0	75.0	53.5
Eastern	94,200	42,500	51,266	7.1	6.4		2.6	18.4	18.9	25.4
China	78,200	24,700	33,373	5.4	5.2		1.7	17.2	16.1	19.1
Japan	9,400	8,500	11,681	18.1	11.1		8.8	21.2	25.6	42.2
Other	6,600	9,300	6,212	16.2	15.3		10.3	33.6	41.9	55.0
Southeastern	42,500	30,900	39,648	15.3	18.3		9.1	59.0	58.2	45.9
Southcentral	109,500	107,000	151,297	20.9	26.5		11.9	79.2	100.8	65.6
Western	2,800	3,000	3,458	3.8	4.8		2.6	13.1	15.3	14.1
Oceania	1,800	2,100	2,156	14.2	12.6		12.3	27.4	28.2	29.0
Pacific Islands*	500	800	1,078	29.1	40.3		23.1	91.2	107.1	167.8
Australia/N. Zealand	1,300	1,300	1,077	9.4	7.7		8.6	15.5	14.8	16.6

*Melanesia, Micronesia, Polynesia

** CR= crude rates per 100,000; ASRW= age standardized rates per 100,000. World standard population. All rates correspond to the most recent compilation of cancer incidence

Table 1-Incidence Rates for Cervical Cancer (Kramer, B. S. editor)

Table 1: Table 1 demonstrates the incidence rates for HPV 16 and 18 in various regions throughout the world. This was helpful in creating our mathematical model because the table gave us something to reference our mathematical model to for the approximate incidence rates in order to accurately predict the effects of the vaccine.

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<u>Region</u>	<u>Testing Method</u>	<u>Study population</u>	<u>Age range of study y</u>	<u>HPV-</u>	<u>DNA</u>		<u>Reference</u>
				<u>(%+)</u>	<u>Age range above 30 **</u>	<u>(%+)</u>	
Africa							
Eastern							
Mozambique	PCR/HC2	Survey	14-61	40.0	31-61	30.5	(2)
Zimbabwe	HC2	Routine screening	25-55	42.8	-----	-----	(3)
Northern							
Morocco	PCR	Hospital case-control	18-70	21.6	35-70	21.6	(4)
Southern							
South Africa (Black)	HC2	Routine screening	-----	-----	35-65	21.3	(5)
Western							
Senegal	PCR	Hospital case-control	-----	-----	35-83	43.7	(6)
America							
Central							
Mexico	PCR	Population-based	<25->65	14.5	35->65	14.1	(7)
Costa Rica	PCR	Routine screening	18-94	16.0	-----	-----	(8)
South							
Colombia	PCR	Survey	13-85	14.9	35-85	8.4	(9)
Argentina	PCR	Survey	15->55	16.6	35->55	13.9	(10)
Northern							
Canada	PCR	Routine screening	15-49	13.3	35-49	9.0	(11)
United states	PCR	Routine screening	16-77	22.5	-----	-----	(12)
Europe							
Eastern							
Russian Federation	PCR	Routine screening	15-45	29.0	31-45	25.5	(13)
Northern							
United Kingdom	PCR	Routine screening	-----	-----	34-70	5.9	(14)
Denmark	PCR	Survey	20-29	18.0	-----	-----	(15)
Southern							
Spain	PCR	Population-based	14-75	3.0	35-75	2.0	(15a)
Italy	PCR	Population-based	25-70	8.6	35-70	7.4	(16)
Greece	PCR	Routine screening	20-55	36.2	-----	-----	(17)
Western							
The Netherlands	PCR	Population-based	15-69	4.6	30-69	4.3	(18)
Germany	PCR	Routine screening	18-70	7.8	36-70	4.9	(19)
France	HC2	Population-based	15-76	15.3	31-76	12.3	(20)
Asia							
Europe							
Japan	PCR	Routine screening	-----	-----	30-78	7.0	(21)
Korea, DR	PCR	Survey	20-74	10.4	35-74	9.6	(22)
Taiwan	PCR	Routine screening	-----	-----	30-64	9.2	(23)
China	HC2	Survey	-----	-----	35-45	18.0	(24)
South Eastern							
Vietnam, North	PCR	Survey	15-69	2.0	35-69	1.9	(25)
Vietnam, South	PCR	Survey	15-69	10.9	35-69	8.0	(25)
Thailand	PCR	Population-based	15->65	6.3	35->65	5.0	(26)
Southcentral							
India (Madras)	PCR	Hospital case-control	23-76	27.7	35-76	28.5	(27)

* HC2= Hybrid Capture 2; PCR = polymerase chain reaction. The HC2 assay was used in 14 samples without PCR amplification.
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Table 2-Prevalence Rates for HPV 16 and 18 (Kramer, B. S. editor)

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Table 2: Table 2 demonstrates the prevalence rates for HPV 16 and 18 in various regions throughout the world. This was helpful in creating our mathematical model because the table gave us something to reference our mathematical model to for the approximate prevalence rates in order to accurately predict the effects of the vaccine.

We also found that the use of condoms does not completely prevent the spread of the virus because condoms may rarely contain holes in diameter of 70 microns and the virus is only one micron wide. Studies show condoms reduce the risk of HPV transmission, including warts in men and cervical neoplasia in women, 39- 80% of the time.

During our investigation for information on the vaccine we discovered that we could not obtain any information on the vaccine because it was proprietary. Dr. Robert Williams, one of our mentors, is a member of RiosNet, a primary care research network group which is involved in the final testing phase of the vaccine's development; hence, Dr. Williams was able to get us the information regarding the effectiveness rate. The effectiveness rate of the vaccine is important to determine whether the benefits will outweigh the costs for development and administration of the vaccine, the first of its kind to effectively reduce the virus cases. We also were able to determine the approximate cost of the vaccine from Dr. Williams: approximately \$100.⁰⁰. This is relevant because due to the cost, many who are at risk for the virus will not receive the vaccine because they cannot afford it.

Project Description

We modeled the effectiveness of the vaccine against HPV types 16 and 18. We did so by creating a mathematical model containing six variables. They are:

1) $prop_Pop_High$, $prop_Pop_Med$, and $prop_Pop_Low$: the proportions of the population with each level of sexual activity; these must add up to one, and effect how the risks are weighted and assessed.

2) $risk_High$, $risk_Med$, $risk_Low$: the 'risks' of a person in the given level of sexual activity to contract HPV 16 or 18;

3) The efficacy (the ability of the vaccine to perform under ideal circumstances) of the vaccine to protect against HPV 16 or 18;

4) The acceptance of the vaccine (i.e. how many people are willing to take the vaccine);

5) The percent of the population who use condoms;

6) The efficacy of the use of condoms;

After long deliberation with Dr. Williams and Betty Skipper, Ph.D., a statistician, we decided that the most appropriate way to model this situation was to model the population as a whole, rather than create individual people and infect them randomly. Thus, we used the approach mentioned in this section. We then got together and

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discussed ways to accurately model a population. Since in a real population there are different levels of sexual activity, we decided to include different levels in our model. We did not want to spend too much time on this, however, so we chose three levels. However, there are most certainly more people with a medium level of sexual activity in a real population than with a high level, so we decided to create proportions of the entire population with a given level of sexual activity. Since someone with a high level of sexual activity will be more exposed to the virus, there will be a higher percentage of them with HPV 16 or 18. Although the vaccine has shown in preliminary tests to be one hundred percent efficacious, we decided to include that figure as well. And of course, not everyone will want to or be able to take the vaccine, so we had to include the acceptance rate in our model.

Results

The Project

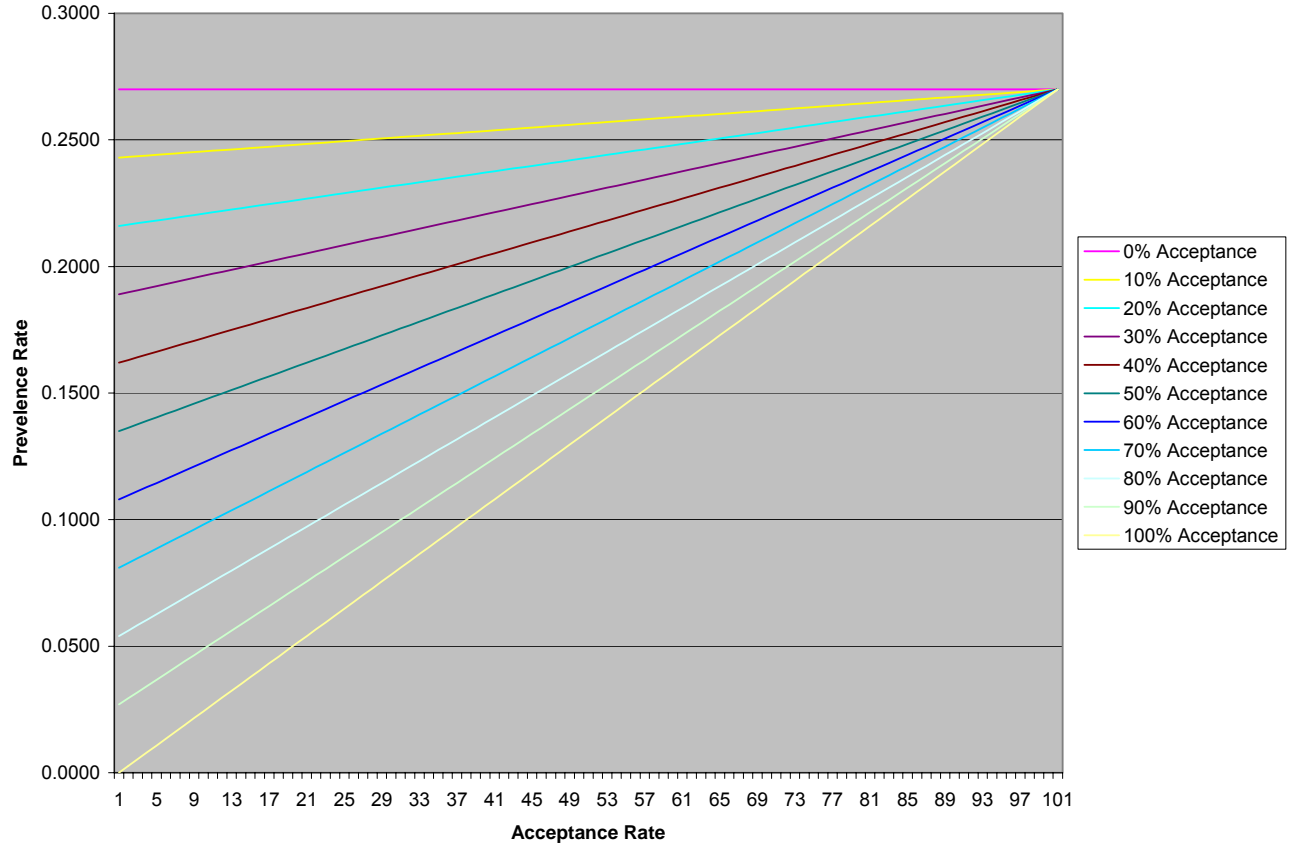
At the beginning of this project, we had high hopes of aiding in the development of this vaccine, but as we went along, we began to realize that this dream would be almost impossible to reach with the time frame we were allotted. We changed our project to monitor how effective this vaccine would be if it was actually released. By just monitoring the effectiveness of this vaccine, we opened up our project to variables we did not expect to have, while omitting some that were expected. We created a mathematical model using Excel, in order to allow easy manipulation of the data and easy-to-use/view numbers. In the months that followed, we modified the algorithm slightly several times, but never by much. Even after we had created a program to work with these numbers, we continued to use Excel because of the ease of creating graphs to represent the data. We found that the proportion of the population with HPV 16 or 18 could be reduced fairly straightforwardly (see Figure 1). Assuming one hundred percent efficacy, if the vaccine was administered to ten percent of the population then the percent of the population with HPV 16 or 18 would drop by ten percent (i.e. if 20% of the population had it before the vaccine was administered, and 10% of the population was given it, only 18% of the population would have HPV 16 or 18 after). In addition, we found that a vaccine would be much more reliable in prevention of the spread of HPV 16

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or 18 than the use of condoms using our estimates for condom use and effectiveness. For one thing, the vaccine would only have to be taken once, while condoms must be used each time. Further, the use of condoms does not completely guarantee that the virus will not be spread. Statistics indicate that the use of a condom is effective on average sixty percent of the time, while the vaccine has been shown to be effective one hundred percent of the time it is taken. Depending upon the acceptance rate, the vaccine could either have a huge impact or a small impact. Figure 1 demonstrates the effectiveness of a vaccine based on its efficacy rate and its acceptance rate.

In order to simulate the period of time before the vaccine is released, we included a possibility for the vaccine to not be present. In conducting a sensitivity analysis on the vaccine acceptance rate and the condom use rate, we discovered that setting the condom use to fifty-percent rate resulted in a thirty-percent decrease in the overall prevalence rate, while leaving the condom use rate at zero and changing the vaccine acceptance rate to fifty-percent resulted in a full fifty percent decrease. Because the two rates will probably be used side-by-side in the real world, though, we tested the two rates combined: this resulted in a sixty-five percent decrease.

Figure 1-Effectiveness with Varying Acceptance and Efficacy Rates



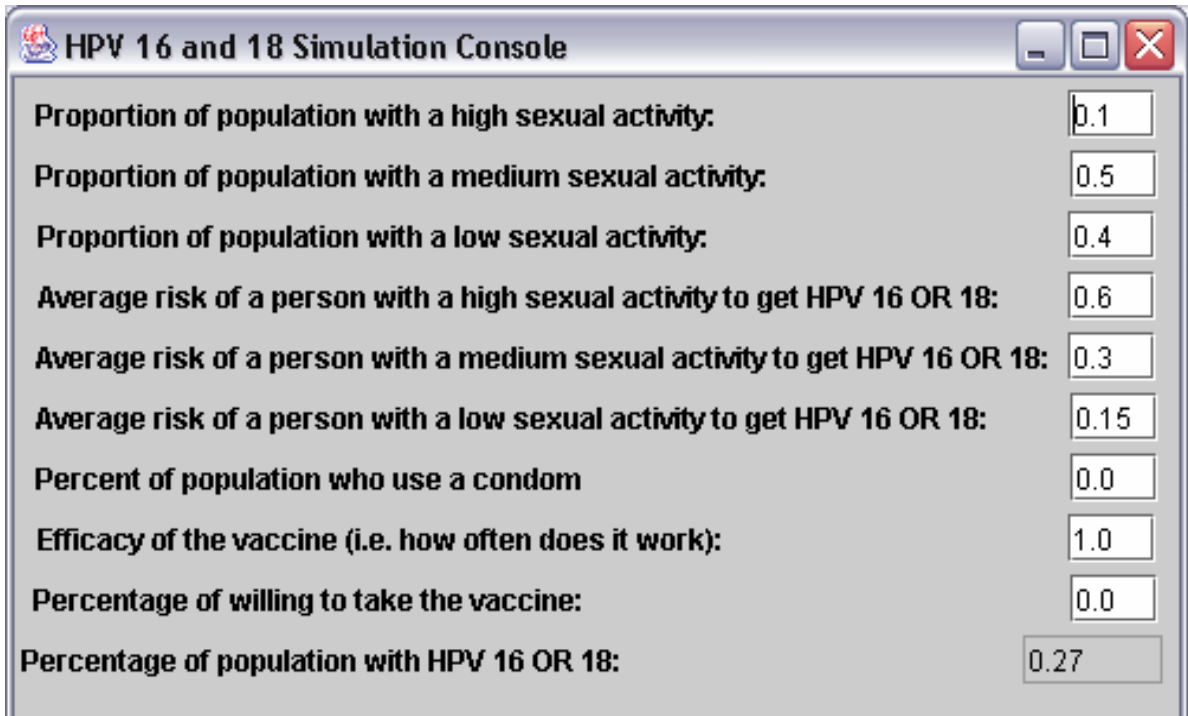
The Code

In addition to the Excel approach we created code to model the problem. Our code produces a Graphical User Interface (GUI) that will allow you to precisely calculate the proportion of the population that is infected with HPV 16 or 18 under the given circumstances. It has nine variables that can be accessed through the nine text fields

positioned in the GUI. By modifying one and pressing [Enter], you can manipulate the data in any way you please.

The first thing it does is declare nine JLabels-strings of text that can be displayed in a Graphical User Interface (GUI). It then declares nine JTextFields-areas with editable text fields which are used to input data. It then declares all variables, which will be used in the program-see for explanations of each. The next thing to appear is its constructor. The first thing it does in the constructor is use JFrame's constructor to set the title bar of the window that will be displayed. It then declares and creates a top-level window to be used for created an effective GUI. After this, it tells the window to arrange its contents in a FlowLayout (i.e. insert the first component in the top-left, the next to its right, and so on until it reaches the border of the window; then, start a new line). It then creates all the JLabels and JTextFields and adds them to the window, adding ActionListeners to the JTextFields. It sets the size of the window and tells the computer to display it. Then, the constructor's done. The method updater is next, which recalculates all the calculated variables, the displays the result of the equation in the appropriate JTextField. Method actionPerformed is called when the user presses 'Enter' in one of the JTextFields, and gets all the variables' new values, setting them correctly. It also calls updater(). The main method starts the whole process and sets the application to close when the 'x' button is clicked.

Figure 2-The GUI created by our code with examples of variables



Conclusions

There are several conclusions we can draw from our results. One, the vaccine will be most effective if targeted and administered to the portion of the population that has a medium sexual activity, based upon our estimates, for several reasons. First, the greatest portion of the population resides in this category, thus it will have the most significant effect on the overall population. Further, if the vaccine were targeted towards the portion with a high sexual activity, there would not be as significant a change upon the total population, because of the small size this group represents. If the vaccine were targeted towards the group with a low sexual activity, they do not have as high a risk, and, as such, they would also not have as high an impact. Even further, after a patient has taken the vaccine, they do not run the risk of contracting the virus, nor even acting as a 'carrier' to the vaccine, meaning that they cannot transport it between to other people. The group with the low sexual activity would not prevent the virus from being spread as much as the group with the medium sexual activity, thus the vaccine would not be as effective.

Two, the prevalence (the amount of the population with the virus) would drop more significantly if the vaccine were advertised as the best prevention, rather than the use of condoms, because of the relatively high (40%) failure rate with the use of condoms. Lastly, the vaccine would be most effective if it were administered to both men and women, rather than just women. It would be less effective for just women

because the men could still transmit the virus to any women he has a relationship with, as opposed to none of them.

Three, the efficacy rate of the use of condoms is .6, where as the efficacy rate for the vaccine is 1. This means that the vaccine will be $1\frac{2}{3}$ as effective as the use of condoms will be under optimal circumstances.

Lastly, if the vaccine is administered to ten percent of the population, the actual impact on the population will be much lower than that, because it will only prevent ten percent of the current infection rate (i.e. If twenty percent of the population had HPV 16 or 18, and the vaccine was given to ten percent of the population, the overall rate would only drop by ten percent of twenty percent, or two percent). The vaccine would have to be administered to a significant portion of the population for it to show noticeable results.

Recommendations

After we had completed our mathematical model and had begun to play with the numbers, it became clear that our algorithm used in modeling the spread of the vaccine was too simple to model the complex situation we had chosen. If we were to continue this project, or do it over again, we would work hard to develop a more complex and accurate algorithm, and, consequently, a more complicated mathematical model.

Most Significant Achievement

After completing the project, we believe that our most significant achievement is our Graphical User Interface (GUI). This stands out in our project because it was a difficult piece of code and it allows viewers easy manipulation of multiple variables. As far as programming goes, the GUI was a great learning experience for all of our team members and allowed us to work together to create a user-friendly code.

Acknowledgements

Challenge team 13 would like to acknowledge the following people for their contributions to this project:

Thomas Allen: for his continuous help in overcoming obstacles in our project, and his support throughout the duration of this project;

Samuel Ashmore: for all of his help in our coding and programming;

Jasmine Safier, Daniel Cummings: for reviewing and editing our final report;

Dr. Robert Williams: for help with the mathematical models, finding research, technical support with the coding, and the idea of the project

Betty Skipper, Ph.D.: A statistician who aided in development of our mathematical model.

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Appendices:

Appendix A: Code

This is our code. It is written in java, and we explain it at the end.

```
/*  
  
 * VirusSpread22.java  
  
 *  
  
 * Created on February 15, 2004, 8:24 AM  
  
 */  
  
package com.swaungcenter.VirusSpread2;  
  
  
import java.awt.*;  
  
import java.awt.event.*;  
  
import javax.swing.*;  
  
/**  
  
 * @author Colin Williams  
  
 * @version 1  
  
 */  
  
public class VirusSpread2 extends JFrame implements ActionListener {  
  
    //Declare all the labels
```

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```
private JLabel prop_Pop_High_Label;  
  
private JLabel prop_Pop_Med_Label;  
  
private JLabel prop_Pop_Low_Label;  
  
  
private JLabel risk_High_Label;  
  
private JLabel risk_Med_Label;  
  
private JLabel risk_Low_Label;  
  
  
private JLabel condom_Use_Label;  
  
  
private JLabel vacc_Eff_Label;  
  
  
private JLabel vacc_Acc_Label;  
  
  
private JLabel overall_Rate_Label;  
  
  
//Declare all the input fields  
  
private JTextField prop_Pop_High_TextField;  
  
private JTextField prop_Pop_Med_TextField;  
  
private JTextField prop_Pop_Low_TextField;
```

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```
private JTextField risk_High_TextField;

private JTextField risk_Med_TextField;

private JTextField risk_Low_TextField;

private JTextField condom_Use_TextField;

private JTextField vacc_Eff_TextField;

private JTextField vacc_Acc_TextField;

private JTextField overall_Rate_TextField;

private JSeparator separator;

//declare all the variables, calculate them if necessary

double prop_Pop_High = .1;

double prop_Pop_Med = .5;

double prop_Pop_Low = .4;

double risk_High = .6;
```

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```
double risk_Med = .3;
```

```
double risk_Low = .15;
```

```
double risk_Based_Level_High = ( prop_Pop_High * risk_High );
```

```
double risk_Based_Level_Med = ( prop_Pop_Med * risk_Med );
```

```
double risk_Based_Level_Low = ( prop_Pop_Low * risk_Low );
```

```
double condom_Use;
```

```
double condom_Effic = 0.6 ;
```

```
double condom_Eff = condom_Use * condom_Effic;
```

```
double vacc_Eff = 1;
```

```
double vacc_Acc = 0.0;
```

```
double vacc_Data = ( 1 - ( vacc_Acc * vacc_Eff ) );
```

```
double overall_Rate_High = ( risk_Based_Level_High * ( 1 - condom_Eff ) * vacc_Data );
```

```
double overall_Rate_Med = ( risk_Based_Level_Med * ( 1 - condom_Eff ) * vacc_Data );
```

```
double overall_Rate_Low = ( risk_Based_Level_Low * ( 1 - condom_Eff ) * vacc_Data );
```

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```
double overall_Rate_All = ( overall_Rate_High + overall_Rate_Med + overall_Rate_Low );
```

```
public VirusSpread2() {  
  
    //Set the title bar of the GUI  
  
    super( "HPV 16 and 18 Simulation Console" );  
  
  
    //get content pane and set its layout  
  
    Container container = getContentPane();  
  
    container.setLayout( new FlowLayout() );  
  
  
    //create label and textfield for first set of variables  
  
    prop_Pop_High_Label = new JLabel( "Proportion of population with a high sexual activity:  
");  
  
    container.add( prop_Pop_High_Label );  
  
    prop_Pop_High_TextField = new JTextField( "" + prop_Pop_High, 3 );  
  
    prop_Pop_High_TextField.addActionListener( this );  
  
    container.add( prop_Pop_High_TextField );  
  
}
```

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```
//create label and textfield for second set of variables

prop_Pop_Med_Label = new JLabel( "Proportion of population with a medium sexual activity:
");

container.add( prop_Pop_Med_Label );

prop_Pop_Med_TextField = new JTextField( "" + prop_Pop_Med, 3 );

prop_Pop_Med_TextField.addActionListener( this );

container.add( prop_Pop_Med_TextField );

//create label and textfield for third set of variables

prop_Pop_Low_Label = new JLabel( "Proportion of population with a low sexual activity:
");

container.add( prop_Pop_Low_Label );

prop_Pop_Low_TextField = new JTextField( "" + prop_Pop_Low, 3 );

prop_Pop_Low_TextField.addActionListener( this );

container.add( prop_Pop_Low_TextField );

//create label and textfield for fourth set of variables

risk_High_Label = new JLabel( "Average risk of a person with a high sexual activity to get HPV 16
OR 18: ");

container.add( risk_High_Label );

risk_High_TextField = new JTextField ( "" + risk_High, 3 );

risk_High_TextField.addActionListener( this );
```

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```
container.add( risk_High_TextField );

//create label and textfield for fifth set of variables

risk_Med_Label = new JLabel( "Average risk of a person with a medium sexual activity to get
HPV 16 OR 18: " );

container.add( risk_Med_Label );

risk_Med_TextField = new JTextField( "" + risk_Med, 3 );

risk_Med_TextField.addActionListener( this );

container.add( risk_Med_TextField );

//create label and textfield for sixth set of variables

risk_Low_Label = new JLabel( "Average risk of a person with a low sexual activity to get HPV 16
OR 18: " );

container.add( risk_Low_Label );

risk_Low_TextField = new JTextField( "" + risk_Low, 3 );

risk_Low_TextField.addActionListener( this );

container.add( risk_Low_TextField );

//create label and textfield for seventh set of variables

condom_Use_Label = new JLabel( "Percent of population who use a condom
");

container.add( condom_Use_Label );
```

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```
condom_Use_TextField = new JTextField( "" + condom_Use, 3 );

condom_Use_TextField.addActionListener( this );

container.add( condom_Use_TextField );

//create label and textfield for eighth set of variables

vacc_Eff_Label = new JLabel( "Efficacy of the vaccine (i.e. how often does it work):
");

container.add( vacc_Eff_Label );

vacc_Eff_TextField = new JTextField( "" + vacc_Eff, 3 );

vacc_Eff_TextField.addActionListener( this );

container.add( vacc_Eff_TextField );

//create label and textfield for ninth set of variables

vacc_Acc_Label = new JLabel( "Percentage of willing to take the vaccine:
");

container.add( vacc_Acc_Label );

vacc_Acc_TextField = new JTextField( "" + vacc_Acc, 3 );

vacc_Acc_TextField.addActionListener( this );

container.add( vacc_Acc_TextField );

//create textfield for results of simulation
```

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```
overall_Rate_Label = new JLabel( "Percentage of population with HPV 16 OR 18:
");

container.add( overall_Rate_Label );

overall_Rate_TextField = new JTextField( "" + overall_Rate_All, 5 );

overall_Rate_TextField.setEditable( false );

container.add( overall_Rate_TextField );

//Create a separator to separate the two parts of the GUI

separator = new JSeparator();

container.add( separator );

//set size and visibility for the GUI components

setSize( 500, 300 );

setVisible( true );

}

//Updater

//Purpose:

//update all variables, the set text in results field

//Called when an action is performed
```

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```
public void updater() {  
  
    double risk_Based_Level_High = ( prop_Pop_High * risk_High );  
  
    double risk_Based_Level_Med = ( prop_Pop_Med * risk_Med );  
  
    double risk_Based_Level_Low = ( prop_Pop_Low * risk_Low );  
  
  
    double vacc_Data = ( 1 - ( vacc_Acc * vacc_Eff ));  
  
  
    double condom_Eff = ( condom_Effic * condom_Use );  
  
  
    double overall_Rate_High = ( risk_Based_Level_High * ( 1 - condom_Eff ) * vacc_Data );  
    double overall_Rate_Med = ( risk_Based_Level_Med * ( 1 - condom_Eff ) * vacc_Data );  
    double overall_Rate_Low = ( risk_Based_Level_Low * ( 1 - condom_Eff ) * vacc_Data );  
  
  
    double overall_Rate_All = ( overall_Rate_High + overall_Rate_Med + overall_Rate_Low );  
  
    overall_Rate_TextField.setText( "" + overall_Rate_All );  
  
}  
  
  
//Handle all ActionEvents from all textfields  
  
public void actionPerformed(ActionEvent event) {  
  
    //Get text from first TextField and set its variable
```

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```
this.prop_Pop_High = Double.parseDouble( prop_Pop_High_TextField.getText() );  
updater();
```

```
//Get text from second TextField and set its variable
```

```
this.prop_Pop_Med = Double.parseDouble( prop_Pop_Med_TextField.getText() );  
updater();
```

```
//Get text from third TextField and set its variable
```

```
this.prop_Pop_Low = Double.parseDouble( prop_Pop_Low_TextField.getText() );  
updater();
```

```
//Get text from fourth TextField and set its variable
```

```
this.risk_High = Double.parseDouble( risk_High_TextField.getText() );  
updater();
```

```
//Get text from fifth TextField and set its variable
```

```
this.risk_Med = Double.parseDouble( risk_Med_TextField.getText() );  
updater();
```

```
//Get text from sixth TextField and set its variable
```

```
this.risk_Low = Double.parseDouble( risk_Low_TextField.getText() );
```

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```
    updater();

    //Get text from seventh TextField and set its variable

    this.condom_Use = Double.parseDouble( condom_Use_TextField.getText() );

    updater();

    //Get text from eighth TextField and set its variable

    this.vacc_Eff = Double.parseDouble( vacc_Eff_TextField.getText() );

    updater();

    //Get text from ninth TextField and set its variable

    this.vacc_Acc = Double.parseDouble( vacc_Acc_TextField.getText() );

    updater();
}

public static void main( String args[] ) {

    // Create a new instance of this class and set it to close when the 'x' is clicked

    VirusSpread2 app = new VirusSpread2();

    app.setDefaultCloseOperation( JFrame.EXIT_ON_CLOSE );

}

}
```

Appendix B: The Mathematical Model

The basic formula we used to model our situation was as follows:

Overall_Rate_All =

$$\begin{aligned} & ((\text{prop_Pop_High} * \text{risk_High}) * (1 - (\text{condom_Use} * \text{condom_Effic})) * (1 - (\text{vacc_Eff} * \text{vacc_Acc}))) + \\ & ((\text{prop_Pop_Med} * \text{risk_Med}) * (1 - (\text{condom_Use} * \text{condom_Effic})) * (1 - (\text{vacc_Eff} * \text{vacc_Acc}))) + \\ & ((\text{prop_Pop_Low} * \text{risk_Low}) * (1 - (\text{condom_Use} * \text{condom_Effic})) * (1 - (\text{vacc_Eff} * \text{vacc_Acc}))) \end{aligned}$$

overall_Rate_All is the total percent of the population with HPV 16 or 18

prop_Pop_High, prop_Pop_Med, and prop_Pop_Low are the proportions of the population that have a given level of sexual activity

risk_High, risk_Med, and risk_Low are the risks of the given groups to receive the virus

condom_Use is the proportion of the population that uses a condom

condom_Effic represents the efficacy of the condoms

vacc_Eff is the efficacy of the vaccine

vacc_Acc is the acceptance of the vaccine

The formula multiplies the risks per group of contracting the virus, multiplies that by the percentage prevented by the use of condoms, then multiplies that by the percentage prevented by the vaccine. It adds these three values together to produce the final percentage with the virus.

Appendix C: Other Figures

Figure 3-A Picture of our Excel Spreadsheet

Level of Sexual Activity	Proportion of Population	% with HPV 16/18 (without vaccine)	Proportion of pop with 16/18 (without vaccine)	Condom Use	Condom Efficacy	Condom Effectiveness	Vacc. Efficacy	Vacc. Accpt.	Vaccine Effectiveness	Overall
High	0.1	0.6	0.06	0	0.6	0	1	0	0	0.06
Medium	0.5	0.3	0.15	0	0.6	0	1	0	0	0.15
Low	0.4	0.15	0.06	0	0.6	0	1	0	0	0.06
										0.27
High	0.1	0.6	0.06	0	0.6	0	1	0.5	0.5	0.03
Medium	0.5	0.3	0.15	0	0.6	0	1	0.5	0.5	0.075
Low	0.4	0.15	0.06	0	0.6	0	1	0.5	0.5	0.03
										0.135
High	0.1	0.6	0.06	0.5	0.6	0.3	1	0	0	0.042
Medium	0.5	0.3	0.15	0.5	0.6	0.3	1	0	0	0.105
Low	0.4	0.15	0.06	0.5	0.6	0.3	1	0	0	0.042
										0.189
High	0.1	0.6	0.06	0.5	0.6	0.3	1	0.5	0.5	0.021
Medium	0.5	0.3	0.15	0.5	0.6	0.3	1	0.5	0.5	0.053
Low	0.4	0.15	0.06	0.5	0.6	0.3	1	0.5	0.5	0.021
										0.095

This is a picture of our mathematical model—created by Excel. It shows examples of the variables and different ways we chose to model our problem.