Conditional Probabilities Assignment

The fundamental cannon of engineering ethics is to "*Hold paramount the safety, health, and welfare of the public*"[i]. However, considerations of public safety, health, and welfare are not always black-and-white--they often require the engineer to weigh the risk versus the benefit of a course of action. The purpose of this exercise is to demonstrate how to apply conditional probabilities to calculate risks. It demonstrates this using the risk of COVID-19 exposure from participating in in-person activities. The user is encouraged to think about risk in a quantitative way, and to develop "*An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts*"[ii].

There are a number of assumptions built into these calculations. I've done my best to provide realistic estimates based on actual data wherever possible, but I welcome you to think about how changing those would affect the calculations.

As of August 21, 2021, Fayette County was reporting an average of 59 new COVID-19 cases per 100,000 people per day[iii]. As of the same date, 58% of Fayette County residents are fully vaccinated (70% among those age 18+)[iv]. Note that President Capilouto has established a goal of getting 80% of the UK campus community vaccinated.

While most states do not track infection rates for vaccinated vs unvaccinated individuals, we can infer these rates from the vaccine efficacy if we assume that both vaccinated and unvaccinated people have the same exposure. The Pfizer vaccine is 88% effective against preventing symptomatic infection from the Delta variant[v], with the other vaccines also effective. Let P_v represent the population of vaccinated people and P_u be the population of unvaccinated people. I_v is the number of infections among the vaccinated population, I_u is the number of infections among the unvaccinated population, and I is the total infections. For simplicity, let's assume a total population of 100,000—we'll convert back to rates later anyway. We can calculate:

$$P_v = 0.58 * 100{,}000 = 58{,}000$$

$$P_u = (1 - 0.58) * 100{,}000 = 42{,}000$$

$$I_v + I_u = 175$$

$$I_v / P_v = (I_u / P_u) * (1 - 0.88)$$

Solving the algebra, we find:

$$I_v = 8.4$$

$$I_u = 50.6$$

Commonly, we see infection rates reported per 100,000 people, which we will label IR for the total infection rate, IR_v for the infection rate among the vaccinated population, and IR_u for the infection rate among the unvaccinated population. The rates are:

$$IR_v = (8.4 / 58{,}000) * 100{,}000 = 14.5$$

$$IR_u = (50.6 / 42{,}000) * 100{,}000 = 120.5$$

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Note that the above numbers are new cases reported per day. It may take 2 to 14 days for COVID symptoms to appear[vi], which means that each of those positive cases may expose others for several days before being detected. Researchers estimate that people who get infected with the coronavirus can spread it to others 2 to 3 days before symptoms start and are most contagious 1 to 2 days before they feel sick[vii]. If we assume that an infected person is contagious for an average of 2 days before the case is detected and the person quarantines, then the rates of infectious individuals in the population are 2 times the IR values shown above. Based on the data above, answer the questions below.

1. Including the instructor and students, we have 55 people in this CE331. Assuming that 80% of our class is vaccinated and the infection rates as calculated above, what is the probability that someone in the class currently has COVID?

2. We will meet for a total of 29 class periods this term. If the infection rates stay at their current levels and 80% of the class is vaccinated, what is the probability that someone will come to the class with COVID at least once this semester?

3. If the infection rates stay at their current levels and 100% of the class is vaccinated, what is the probability that someone will come to the class with COVID at least once this semester?

4. Next, we consider what might happen if we are exposed. Masks offer a layer of protection both for you and those around you[viii]. While the exact numbers vary based on the type and the study[ix], let's estimate that wearing a mask cuts your risk of infection by 65%[x], and also that an infected person wearing a mask cuts the risk of transmission to others by 65%. Given these estimates, how much is your risk of infection cut if all parties are wearing masks?

5. If both parties are masked, and you are also vaccinated with a vaccine that has 88% efficacy against symptomatic infection, how much have you reduced your risk combined through both masking and vaccination?

6. Assume exposure would result in a 25% chance of transmission to a single individual without masking or a vaccine, and assume that in an unventilated classroom everyone is exposed. Given the probability of an exposure in the first class calculated in question 1, given that we are all wearing masks, and given an 80% vaccination rate, what is the probability that at least one person will catch COVID from the first class?

7. In addition to preventing infection, the vaccines are highly effective at preventing hospitalization and death, with most "breakthrough" cases mild[xi]. In Kentucky, the COVID hospitalization rate is 41 times higher for unvaccinated people, and the death rate is 23 times higher for unvaccinated people[xii]. While younger individuals are less likely to have a COVID infection become severe[xiii], hospitalizations among young adults[xiv] and children[xv] are at their highest levels yet in part due to lower vaccine update, or ineligibility in the case of children under 12. In Fayette County, about 1% of COVID cases among people ages 20 to 24 resulted in hospitalization[xvi] (assume this rate applies to unvaccinated individuals). If everyone is in that age range, what is the probability that at least one of the unvaccinated individuals in this class his hospitalized due to catching COVID in the first class?

8. Based on the calculation in 7, and assuming the rates stay constant, what is the probability that any unvaccinated person in this class is hospitalized due to catching COVID in any of the 29 class periods?

In reality, the infection rates are not constant. If we all mask and vaccinate, the rates will come down, and these probabilities will be lower than calculated above. If we don't, the infection rates will continue to rise until it burns through the population.

9. Please share any additional reflections on this assignment, your ability to make informed judgments when facing risk, and the ethical and professional responsibilities of engineers in the context of the COVID-19 pandemic.

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