Physical Context:

The model featured in the article "Dynamic modelling of the impact of public health education on the control of emerging infectious disease" by Guihua Li and Yiking Dong attempts to describe the impact that public health education or knowledge has on the spread of infectious diseases. At the beginning of an epidemic, the influx of news reports and transmission of information about the new disease has a psychological impact on the public. The more knowledge the public has about the disease, the less likely that disease is to spread in the population. Working under the assumption that public health education is an effective control of the spread of infectious diseases, the article divides public health education into two categories: mass communication and interpersonal communication. Mass communication is done mainly through the use of widespread communication networks such as television news or the internet. Interpersonal communication is done through interactions between groups or individuals, but is not limited to word-of-mouth transmission. Local hospitals and public health clinics reaching out to their communities is a prime example of interpersonal communication. An important thing to note is that while a population may experience both types of communication, they may experience them in different quantities. The authors aim to build a model that takes into account the effects of both mass communication and interpersonal communication, and show how both types of communication have significant effects on the control of emerging epidemics.

Model:

The model the authors employ divides the population into several different subgroups: susceptible, infected, and recovered. Subdividing the subgroup of the susceptible population into those who are oblivious to the disease and how it is spreading and those who have a certain understanding of the disease yields 4 groups of individuals. The model can be broken down into the following system of equations.

$$\frac{dS_1}{dt} = A_1 - dS_1 - \gamma S_1 - \delta S_1 S_2 - \beta_1 S_1 I,$$
$$\frac{dS_2}{dt} = A_2 - dS_2 + \gamma S_1 + \delta S_1 S_2 + (1-p)\beta_1 S_1 I - \beta_2 S_2 I,$$
$$\frac{dI}{dt} = p\beta_1 S_1 I + \beta_2 S_2 I - dI - \alpha I - \nu I,$$
$$\frac{dR}{dt} = \nu I - dR,$$

Where S_1 is the unaware susceptible population, S_2 is the aware susceptible population, I is the infected population, and R is the recovered population. The rest of the parameters are displayed in the table below.

A_1, A_2	Rate of recruitment into unaware and aware susceptible populations, respectively
d	Rate of the natural death
γ	Rate of awareness spread by mass communication
δ	Effective contact rate from aware susceptible to unaware one
β_1	Effective contact rate from infected to unaware susceptible
$p\beta_1$	Probability of disease transmission per contact by an infective
$(1-p)\beta_1$	Probability of disease awareness transmission per contact by an infective
β_2	Effective contact rate from infected to aware susceptible
α	Death rate due to the disease
ν	Recovery rate of infected

The authors assume that the aware susceptible population will be infected at a lower rate than those in the unaware susceptible population, and that the transmission rate of information is faster than the infection rate of the susceptible population.

Since the first three equations of the system are independent of the fourth, the authors reduce the model down to just a system consisting of the first three equations, which will be referred to as system (2).

The paper uses a parameter called the basic reproduction number, R_0 which measures the transmission potential of a disease. R_0 is the average number of secondary infections produced by a given infected individual in a completely susceptible population. The parameter describes whether or not an infectious disease will spread through a population, with $R_0 < 1$ predicting that the infection can't spread through the population and will eventually die out, and $R_0 > 1$ predicting that the infection can spread through the population. The authors use this parameter to describe the basic reproduction number of the unaware susceptible population and the aware susceptible population, S_1, S_2, respectively.

<u>Results:</u>

The authors define two types of equilibria, a disease-free equilibrium, where there are no diseases present, and an endemic equilibrium where there is some amount of infected and susceptible individuals. First, the authors explore the disease-free equilibrium of system (2), finding that the equilibrium always exists. They also find that if $R_0 < 1$, then there is no endemic equilibrium and the disease dies out. If $R_0 > 1$, the researchers find two subcases. First, if $1 < R_2 < R_1$, then there exists a single, unique endemic equilibrium. Secondly, if $R_1 > 1 > R_2$, then there exists an endemic equilibrium when $R_1 > h_1(R_2)$, and there is no endemic equilibrium when $R_1 \le h_1(R_2)$.

Next, the authors study the local stability of the disease-free equilibria and the endemic equilibria found previously. Using a Jacobian matrix and finding the characteristic equation and roots of the resulting quadratic polynomial, the authors find that the roots have negative real parts, and so they conclude that the disease-free equilibrium is locally asymptotically stable if and only if $R_0 < 1$. In a similar fashion, the authors compute the stability of the endemic equilibrium of system (2), and find that it is locally asymptotically stable.

Finally, the paper examines the global stability of the equilibrium of system (2), given some assumptions detailed below.

(H) For $0 \leq S_i \leq S_i^0, i=1,2, I>0,$

$$(S_1 - S_1^*)(\frac{S_1^*}{S_1} - \frac{S_2^*}{S_2}) \leq 0, \qquad (S_1S_2 - S_1^*S_2^*)(\frac{S_1^*}{S_1} - \frac{S_2^*}{S_2}) \leq 0,$$

$$(S_1I - S_1^*I^*)(\frac{S_1^*}{S_1} - \frac{S_2^*}{S_2}) \leq 0, \qquad (S_1I - S_1^*I^*)(\frac{S_2^*}{S_2} - \frac{I^*}{I}) \leq 0,$$

$$(\frac{S_2^*}{S_2} - \frac{I^*}{I})(\frac{S_1^*}{S_1} - \frac{S_2^*}{S_2}) \leq 0.$$

With the assumption (H), the researchers find that if the endemic equilibrium exists, the equilibrium must be globally asymptotically stable.

The researchers find that when the incidence rate of aware and unaware individuals is equal, the basic reproduction number will not be affected by any type of information during an epidemic. However, in modeling reality, they default back to one of their original assumptions, that the incidence rate of aware individuals is greater than the incidence rate of unaware individuals.

In order to model the basic reproduction rate number R_0 as it relates to parameters γ, δ (rate of awareness spread by mass communication, effective contact rate from aware susceptible to unaware one) under the assumption above, the researchers use the equation,

$$\begin{aligned} G(R_0, \gamma, \delta) = {} & d^2\delta(d+\alpha+\nu)^2R_0^2 - d(d+\alpha+\nu)[(A_1+A_2)(p\beta_1+\beta_2)\delta \\ & + d(p\beta_1-\beta_2)(d+\gamma)]R_0 + p\beta_1\beta_2\delta(A_1+A_2)^2 \\ & + d(p\beta_1-\beta_2)[d(p\beta_1A_1+\beta_2A_2)+\beta_2\gamma(A_1+A_2)] \\ = {} & 0. \end{aligned}$$

taken with parameters listed below.

$A_1 = 10,\ A_2 = 2,\ d = 0.6,\ \beta_1 = 0.75,\ p = 0.4,\ \beta_2 = 0.5,\ \alpha = 0.2,\ \nu = 0.8$

The result of this analysis is that R_0 will decrease as γ increases, meaning that mass communication can help prevent the spread of disease. They also find that R_0 will firstly increase as δ increases, then decrease later, meaning that interpersonal communication can contribute to the spread of disease at first, but will later aide in prevention. The authors offer this as an explanation for the phenomena of information distortion and widespread panic during the early stages of an epidemic. However, as populations learn more about the disease, interpersonal communication can contribute to lowering the threshold for disease invasion.

The paper concludes that mass communication and interpersonal communication have a positive influence on the control of emerging infectious diseases. Thus, they conclude that it is important to public health that there is an increase in disease awareness and communication between individuals.

<u>My Reaction:</u>

I thought that aspects of this paper were interesting. I did not know about basic reproduction numbers, and I thought it was cool to link that concept back to the differential equations that we modeled in class that described populations and their growth, or at least see the similarities. I think that the concept of the paper was the most interesting thing to me. I think it's really cool how they can put together a system of differential equations that links different kinds of public health communication to the control of the spread of disease. I also really liked the visualization of Figure 3 that linked the three parameters. I thought that the 3D graph was actually really illustrative, even if it seemed confusing at first. However, the article is not without its drawbacks. I did not like Figure 1. I thought that it was confusing and that it did a worse job of showing us what the model looked like than the system of equations did. None of the parameters' meanings were immediately obvious from it and the arrows made things even worse. Overall, I think this article is kind of weak. I think it serves very well as a simplified model, but I think that more subdivisions are necessary in order to completely model this complex situation. For example, mass communication and interpersonal communication must be subdivided because I don't believe that that complex of a social phenomena can be sufficiently categorized into just two categories. Additionally, the suggestions that the authors throw out at the end seem illogical and like they were added at the last minute as a kind of "fluff".