AARMS Project 2023

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1 Base Model

We will use a deterministic time-independent SEIR model on a closed population. In other words we will not consider any birth or death (natural or disease related) within the base model itself. The compartments will have susceptible, exposed, infected, and recovered individuals, as proportions of the total population. We are using a very simplistic compartmental model so that our main focus can be on changes in NPI compliance due to pandemic fatigue.

$$\begin{cases} \frac{dS}{dt} = -\lambda(t)SI, \\ \frac{dE}{dt} = \lambda(t)SI - \kappa E, \\ \frac{dI}{dt} = \kappa E - \gamma I, \\ \frac{dR}{dt} = \gamma I. \end{cases} \tag{1}$$

Where,

- γ is the recovery rate of individuals infected with COVID-19,
- $\frac{1}{\kappa}$ is the mean latent period of COVID-19,
- λ is the force of infection.

2 Accounting for changes in NPI adherence

To modify this base model to account for NPI use during the pandemic, as well as to account for those changes in NPI adherence, we change the equation of the force of infection, from equation 2 to equation 3. Where the effect NPI implementation has on the force of infection is represented similarly as in the paper by N'konzi et al. [1].

$$\lambda(t) = \beta_0 \tag{2}$$

$$\lambda(t) = \beta_0(1 - \mu(0.5tanh(x(t)) + 0.5)) \tag{3}$$

Where,

- β_0 is the effective contact rate of the disease with no control measures (NPIs) implemented,
- μ is the efficiency level of the NPIs implemented,
- $x(t)$ is the percent level of adherence to NPIs within the total population.

It is important to note that $x(t)$ is transformed within the $0.5tanh(x(t))+0.5$ function to ensure that all values are bounded by 0 and 1. So if we say the bounded percent level of adherence is represented by $x_b(t)$, it is equal to equation 4. The paper by Glaubitz used *tanh* as a way of bounding similarly [2].

$$x_b(t) = 0.5tanh(x(t)) + 0.5 \tag{4}$$

Knowing that the percent level of adherence to NPIs would decrease with the amount fatigue, f, but would increase with increase risk of infection; we get equation 5.

$$\frac{dx}{dt} = -f + \beta_0 I \tag{5}$$

Where,

- f represents the level of fatigue within the population,
- $\beta_0 I$ is the probability of getting infected.

3 Determining Parameters

We wanted to keep this model for a general infectious disease and so we took our parameters from general ranges for a respiratory infectious disease, similar to COVID-19 or seasonal influenza. For some general guidance on what values were reasonable, we looked to similar model studies like those by N'konzi et al and by Glaubitz and others cited [1, 2, 3, 4]

The last few parameters will be the parameters we investigate. So we will vary the μ parameter, which is the effectiveness as NPIs being used. This could include social distancing, mandatory quarantine, and mask use. We will also vary the f parameter to investigate how this affects the percent adherence level with NPIs and the number of infected individuals.

4 Simulations

We will show some simulations to discuss how our two parameters of interest (f and μ) affect the dynamics of the infected individuals within these situations. Below, table 1, shows the parameter values used for the simulations, and table 2, shows the initial conditions used as well.

Parameter	**1**	**3**
f	Varies	0.01
μ	1	Varies
β	1.1	1.1
κ	$\frac{1}{6}$	$\frac{1}{6}$
γ	$\frac{1}{8}$	$\frac{1}{8}$

Table 1: List of parameters used for simulations.

Initial Condition	**1, 3**
S_0	0.95
E_0	0
I_0	0.05
R_0	0
x_0	0.8

Table 2: List of initial conditions used for simulations.

4.1 Varying Fatigue levels

Varying the fatigue parameter, f, while keeping all other parameters constant (shown in table 1, gave us figure 1 and figure 2. With this figure we looked at $f = 0.005, 0.01, 0.03, 0.05, 0.09$. As this value decreased, the waves created are pushed further back in time, as can be seen when $f = 0.005$ compared to $f = 0.01$. When $f = 0$ there will be no waves, and the number of infected individuals will decrease and remain at zero new infections. As this parameter increases, the waves become closer together and are seen early in the disease progression. This eventually leads to when the fatigue levels remain higher than the risk of getting the disease $\beta_0 I$ and the infected individuals end up all within one large first wave only. The change in the dynamics of the waves of infected individuals, follows with the change in NPI adherence $x_b(t)$ plotted in Figure 2. The amount of change in NPI adherence (size of waves) and how spread out the waves are decreases as the fatigue level increases.

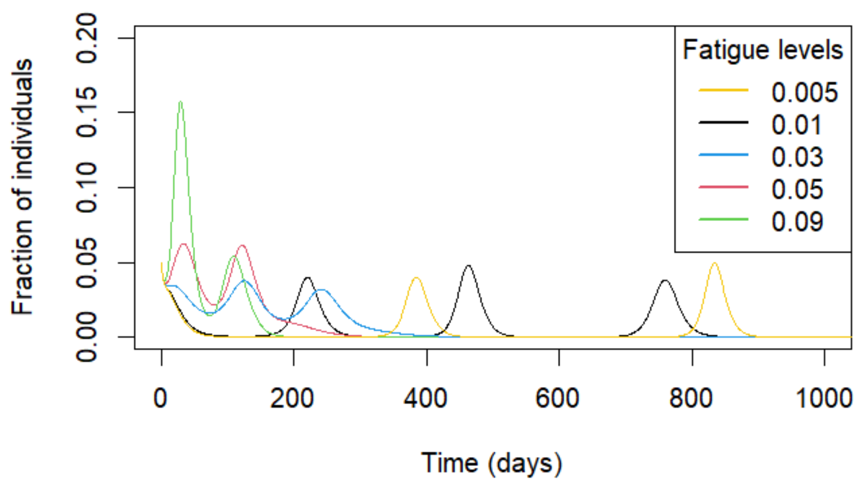

Figure 1: Varying fatigue level f within the SEIR model changing proportion of infected individuals, with $\beta = 1.1$, $\kappa = 1/6$, $\gamma = 1/8$, and $mu = 1$.

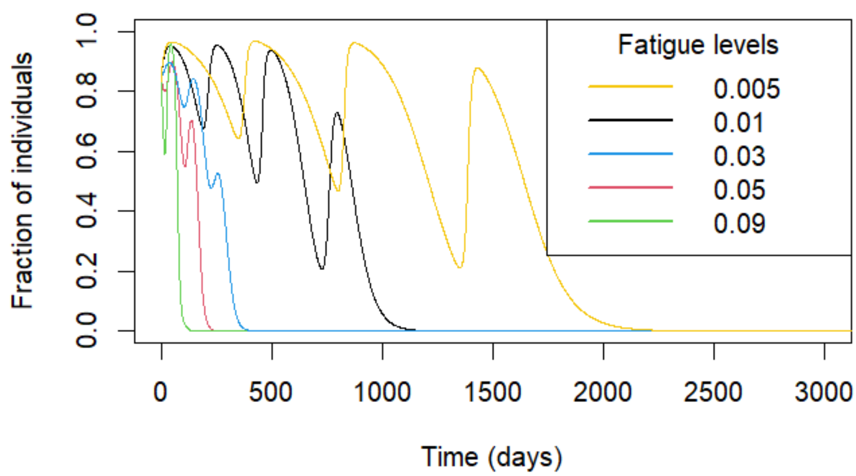

Figure 2: Varying fatigue level f within the SEIR model changing proportion of individuals complying with NPIs, with $\beta = 1.1$, $\kappa = 1/6$, $\gamma = 1/8$, and $mu = 1$. *Note: Scale was changed in this figure to fit properly.*

4.2 Varying NPI Efficiency Level

When varying the NPI efficiency levels, μ, all other parameters were kept constant (shown in Table 1 and is shown in Figure 3 and Figure 4. We looked into $\mu = 1, 0.9, 0.8, 0.7$. As you can see, there is a threshold NPI efficiency level at which waves will stop occurring. Within the simulated situation, this value was 75 percent efficiency. It is important to note that this value will change depending on what the other parameters are set to. It is important to note that a second wave is there for 80 percent efficiency, but it is beyond the axis limit on the plot. If NPI efficiency is low enough, the probability of getting infected, $\beta_0 I$, stays above the level of fatigue and so the level of adherence to NPIs will keep increasing and there will only be one wave. This follows with the change in level of adherence to NPIs shown in Figure 4. These waves in adherence also disappear as the NPI efficiency drops below 75 percent.

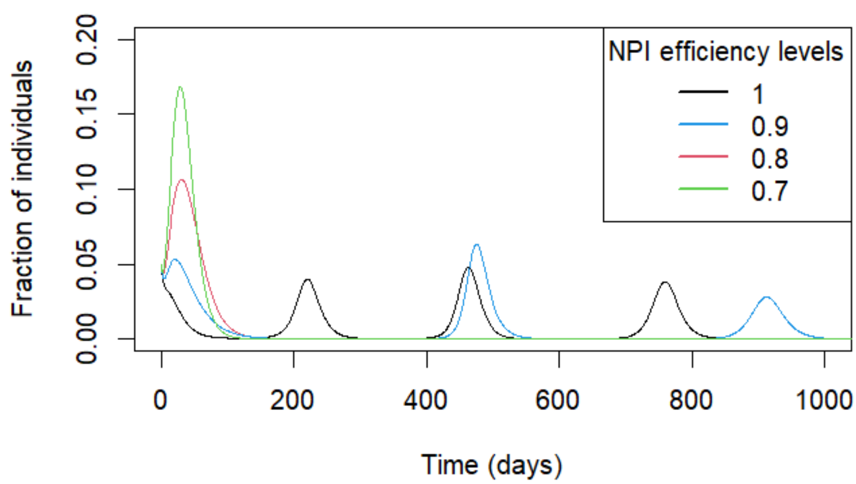

Figure 3: Varying NPI efficiency level μ within the SEIR model changing proportion of infected individuals, with $\beta = 1.1$, $\kappa = 1/6$, $\gamma = 1/8$, and $f = 0.01$.

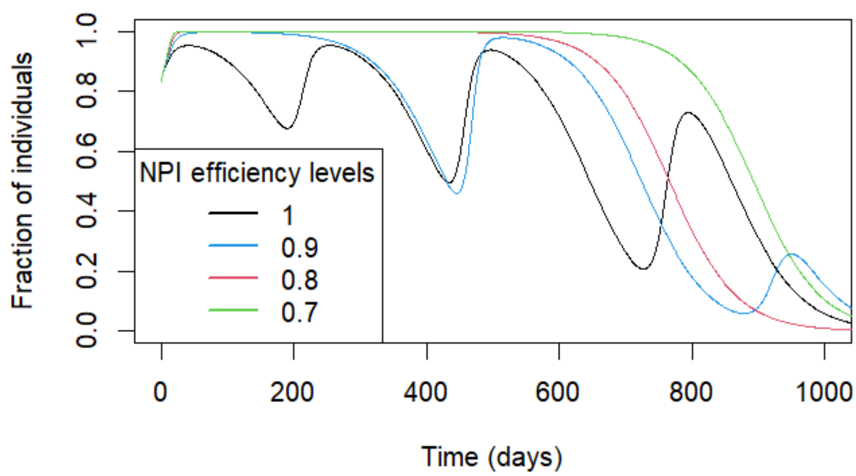

Figure 4: Varying NPI efficiency level μ within the SEIR model changing proportion of individuals complying with NPIs, with $\beta = 1.1$, $\kappa = 1/6$, $\gamma = 1/8$, and $f = 0.01$.

5 Discussion

World Health Organization talking about pandemic fatigue [5]. This was released due to pandemic fatigue during the COVID-19 pandemic, but it is discussed broadly for any policy in which individual compliance is necessary. They define pandemic fatigue as "demotivation to follow recommended protective behaviours, emerging gradually over time and affected by a number of emotions, experiences and perceptions" [5]. The discussion here builds on this release from WHO and a Science Briefs release for COVID-19 Advisory for Ontario [6].

Four key strategies that are discussed for governments to help reduce pandemic fatigue within the population:

1. Understanding the public,
2. Engaging the public within the solution,
3. Allow the public to live their lives, while reducing the risk,
4. Acknowledge the hardship that the public is experiencing [5].

5.1 Understanding the public

Putting in the effort to understand individuals will always help further communication. Discussing with general members of the public and/or through public organizations, can help the government understand what motivates the public to comply to these policies [5, 6]. This open communication with the public will help the government test new initiatives/policies and communicate what the government needs of the public [5, 6]. This can also in general help identify high risk populations or groups within the public that may need further attention from the government [5].

5.2 Engaging the public

Engaging civil society groups within the public, will not only further communication between the government and the public to increase understanding but will also increase resources and local trust [5, 6]. As many members of local groups are generally trusted, using this as a form of communication with the public and working with these groups can help increase the trust the public has in complying with these policies [5, 6]. While the government communicates their needs and their ideas for possible initiatives, these local groups can help make suggestions about these initiatives and give guidance about their knowledge of the local public [5, 6].

5.3 Allow people to live their lives, while reducing risk

The big message in this is to try to switch initiatives to let people do things differently rather than not be able to do things at all [5]. A good example of this would be the implementation of a lockdown that stops individuals from seeing their extended families, which stops them from doing this activity. This can be changed to individuals being able to see their families, but having to maintain distance and use masks. This way the public can still visit their family, just differently. This will be accepted much easier than stopping individuals completely [5]. In this area, it is important for governments to consider all possible cultural implications of initiatives as well to ensure all members of the public can still engage in their culture in at least some meaningful way [5, 6]. An important way to do this is to give guidance of high and low risk activities for the public, and to increase education on policies and the disease [5].

5.4 Acknowledge the hardship that the public is experiencing

The most important strategy to acknowledge the hardship of the public is communication [5]. The government should communicate their understanding and show that they are trying to address these hardships and to reduce these when and where possible [5, 6]. Discussing and communicating with the public can further help identify the hardships or barriers that the public is having the most trouble with and can help identify what should be more focused on. It is also important to acknowledge the efforts of the public and not point blame towards them [5, 6].

These strategies build off of the five principles suggested for any policy or communication:

1. Transparency,
2. Consistency,
3. Predictability even when things are unpredictable,
4. Fairness,
5. Avoid mixed messages [5].

Any of the four key strategies will help towards achieving the list of principles given above [5]. Maintaining transparent and open communication with the public, will build further trust in the decisions the government is making [5, 6]. By striving for consistency, predictability even when things are unpredictable, and fairness for all members of the public, this will increase trust and general motivation within the public [5, 6]. Increasing the public's motivation to comply with policies, will fend off fatigue causing that reduction in NPI compliance, which as we have seen can cause new epidemic waves.

References

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