# Examination of the Effect of Restriction on Non-Vaccinated People with COVID-19

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*Abstract*—**COVID-19 is causing a global pandemic. Vaccines have already been developed and are being promoted in many countries. In the UK, most of the lockdown regulations were lifted in July this year because of the widespread use of vaccines. Many regulations have been lifted in Japan since October. As deregulation progresses, it is necessary to consider efficient measures to spread infection, assuming that a pandemic will occur again. Therefore, in this study, we examined the effect of restricting movement only to those who have not been vaccinated.**

## I. INTRODUCTION

The pandemic by COVID-19 is spreading worldwide. The basic reproduction number of this virus was estimated to be 1.4-2.5 [1]. In other words, one infected people infects an average of 1.4-2.5 people. This strength of infectivity has triggered a global pandemic. The incubation period that characterizes this virus was estimated to be 5.1 days [2].

Before the vaccine was developed, many areas took some steps to prevent the spread of the virus. Such measures include the use of masks, social distance, border blockages, outing restrictions, and temporary suspension of universities and businesses. Simulations have shown that these measures have some effect [3].

Vaccines that are effective in preventing COVID-19 infection have already been developed. Governments are working to popularize this vaccine. With the spread of vaccines, the number of newly infected people is declining. As a result, in Japan, restrictions on the movement of people will be withdrawn, and the market where people gather will reopen. Under such circumstances, it is important to predict the spread of infection when the movement of people in the vaccine environment resumes.

There are two methods for predicting the spread of virus infection. It is a method using a mathematical model and a simulation method using multiple agents (Multi-Agents-Simulation: MAS). When a mathematical model is used, it is relatively easy to calculate and is effective for predicting a macro range. MAS, on the other hand, is useful for predicting local ranges.

In recent years, there have been many studies on COVID-19 infection prediction using mathematical models. However, there are not many predictions using MAS. MAS considering vaccines is even less. Many studies also randomly determined agents to stop movement when estimating the effect of movement restriction. We believe that more effects can be achieved by arbitrarily deciding which agent to stop moving. Therefore, in this study, MAS was performed with the aim of comparing changes in the infection status between the case where the movement of random agents was regulated and the case where the movement was regulated by selecting an agent who had not been vaccinated.

## II. MULTI – AGENTS - SIMULATION (MAS)

MAS is a method that controls the movements of multiple agents individually and simulates the interaction of each agent. It is possible to specify attributes such as age and status for the agent. Since it is possible to control the movement of individual agents, it is possible to obtain detailed information that cannot be analyzed by mathematical models. Therefore, it is used for social experiments on computers. In this study, MAS is effective in distinguishing the behavior of vaccinated and non-vaccinated agents.

## III. ANALYTICAL MODEL

In this study, we used an extension of the SEIR model, which is often used for infectious disease analysis. The SEIR model is a mathematical model that divides the entire population into S (Susceptible People), $E$ (Exposed People), $I$ (Infected People), and $R$ (Recovered / Removed People) groups and estimates the time change of each group. be. In this study, in addition to the above four groups, three groups, $I'$(Not Symptomatic Infected People), $M$ (Minor Illness People), and $G$ (Grave Illness People), were added. Figure 1 shows the transition diagram of each group.

Upon contact with $I$ or $E$, $S$ becomes infected and changes to E. $E$ becomes ill over time and changes to infected people $I$ with symptoms and infected people $I'$ without symptoms. After a lapse of time, $I$ changes to $M$ or $G$ and is quarantined. $M$ and $G$ change to $R$ or $G$ over time.

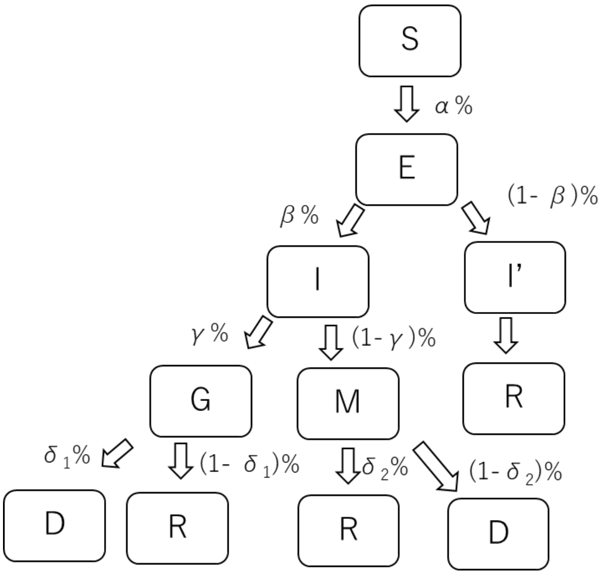

Fig. 1. State transition diagram

## IV. SIMULATION

The vaccine prevalence in Japan on October 25 was 78.1% for the first vaccination and 74.3% for the second vaccination [4]. Based on this data, simulations were performed in four patterns in an environment where vaccinated people exist.

Sim.1: No vaccine. No movement restrictions.
Sim.2: With vaccine. No movement restrictions.
Sim.3: With vaccine. There are movement restrictions. 10% of random agents are inactive.
Sim.4: With vaccine. There are movement restrictions. 10% unvaccinated agents cease activity.
Table 1 shows the behavior rules of each agent.

Table 1. Agent behavior rules

| | |
|---|---|
| Daytime | Gather at company or school |
| Evening: | Free to move in the town |
| Night | Stay home |
| Holidays | Free to move in the town |

## V. CONDITIONS

Table 2 shows the values of each parameter used in the simulation. In general, the infection probability $\alpha$ is difficult to estimate. Therefore, referring to the estimated basic reproduction number of COVID-19 [1], the parameters were adjusted so that the number of infected people infected in one day would be about 2.

The image of the simulation is shown in Fig. 2.

Table 2. Coefficients of the model

| | |
|---|---|
| Number of agents | 400 people |
| Number of Initially infected | 20 people |
| Period of exposed | 5.1 days |
| Period of Disease duration | 10 days |
| Plobability of infection($\alpha$) | 50% |
| Probability of symptom($\beta$) | 80% |
| Plobability of severe($\gamma$) | 5% |
| robability of death($\delta_1$) | 1.30% |
| robability of death($\delta_2$) | 9.80% |
| Plobability of Infection prevention (Once vaccination) | 61% |
| Plobability of Infection prevention (Twice vaccination) | 93% |
| Probability of prevention of severe (Once vaccination) | 68% |
| Probability of prevention of severe (Twice vaccination) | 96% |
| Period of isolation | 2days |

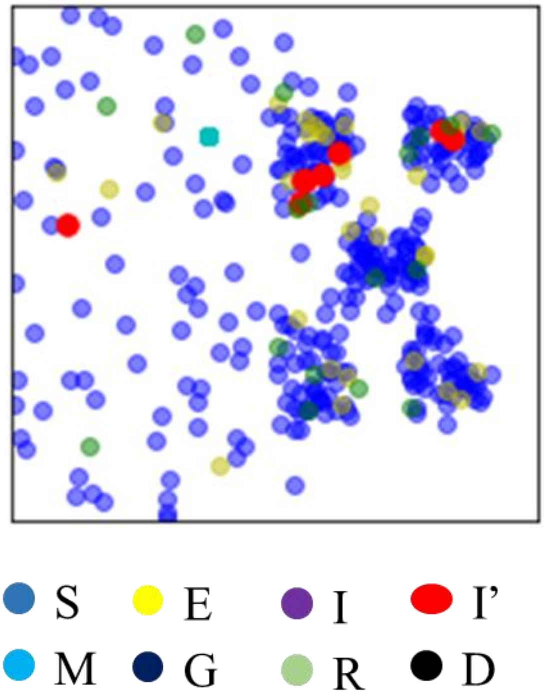

Fig. 2. Simulation image

## VI. RESULT

Figure 3 shows the changes in the number of newly infected people observed in Sim.1 and Sim.2. This is the amount of increase in *M* and *G*. *I'* is not symptomatic and is not observed, it is not included in the number of infected people.

From Figure 3, the peak infection is around 12 days in the absence of vaccine. On the other hand, when more than 70% of agents are vaccinated, there is no major peak and few infected people continue to occur for a long period of time.

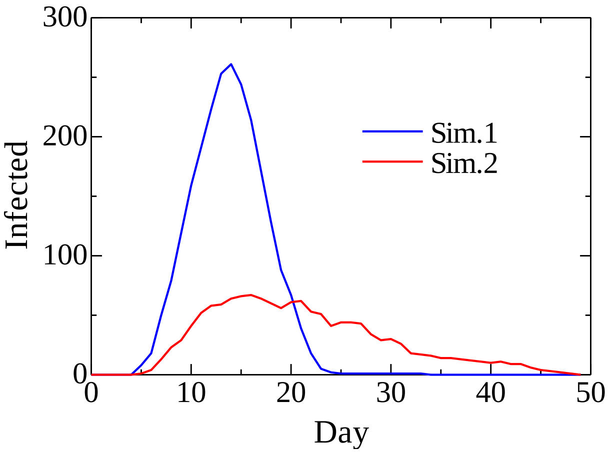

Fig. 3. Changes in the number of newly infected people (Sim.1, Sim.2)

Figure 4 shows the transition between illnesses in infected agents. The peak of Sim.1 is high and the peak of Sim.2 is low.

In general, a sharp increase in the number of infected people causes medical collapse. The results show that the spread of vaccines is effective in reducing peak infections and preventing the problem of medical confusion.

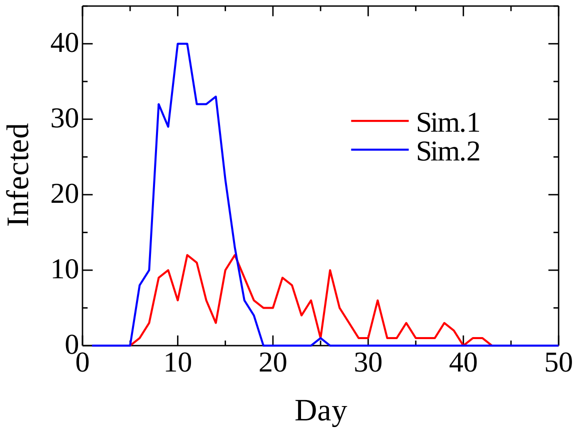

Fig. 4. Changes in the number of disease agents (Sim.1, Sim.2)

Fig. 5 shows the transition of the number of newly infected people observed from Sim.2 to Sim.4.

Looking at Figure 3, it is shown that from Sim1 to Sim3, there is no sudden peak of infection, and a small number of infected people continue to occur for a long time. In addition, it can be seen that there is no significant change in the spread of infection in each simulation.

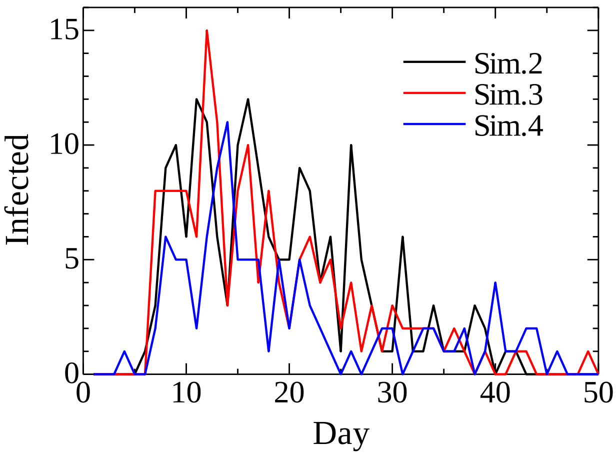

Fig. 5. Changes in the number of newly infected people (Sim.2, Sim.3, Sim.4)

Next, Table 3 shows the total number of infected people and the number of deaths.

Table 3 shows that the total number of infected people is lowest in Sim.3. Furthermore, the number of infected people in Sim.4 is 29.4% lower than in Sim.3. This indicates that the number of infected people can be reduced by 29.4% by selecting unvaccinated agents and implementing movement restrictions.

On the other hand, the number of deaths is the maximum value in Sim.1 and the minimum value in Sim.2. However, due to the extremely small number of deaths, no significant difference is shown.

Table 3. Total number of infected people and number of deaths

| | Infection | Death |
|---|---:|---:|
| Sim.1 | 302 | 5 |
| Sim.2 | 177 | 1 |
| Sim.3 | 153 | 4 |
| Sim.4 | 108 | 3 |

## VII. DISCUSSION

In Table 3, there was a difference in the total number of infected people, but there was no significant difference in the number of deaths. The cause may be that there is a large difference in mortality rate by age. It is also reported that the mortality rate in the 70s is about 93 times higher than that in the 30s. This time, the ages of all agents were regarded as the same, and the simulation was performed assuming an average mortality rate. As a result, the mortality rate was low and the number of deaths was small, so it is considered that there was no significant difference in the number of deaths.

## VIII. CONCULUSION

In this study, we investigated the infection prevention effect when selective movement regulation was implemented in a model considering vaccines. As a result, it was found that the number of infected people was reduced by 29.4% when the movement regulation was implemented by selecting the non-vaccinated people as compared with the random movement regulation. In addition, it is considered that the number of deaths can be discussed by considering the age in the simulation model.

## REFERENCE

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