Multi-agent simulation of trust in vaccination

Presentation

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SARS-CoV-2 and COVID-19

- Emergence in late December 2019

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- SARS-CoV-2 variants
- Vaccines
- Misinformation and disinformation

Problem

- Agent-based simulations on vaccine effectiveness

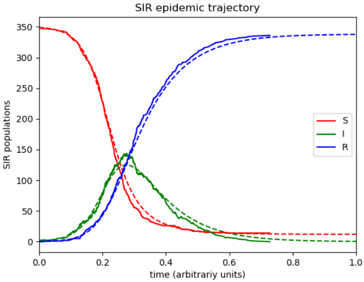
- Public trust in vaccines

Goal

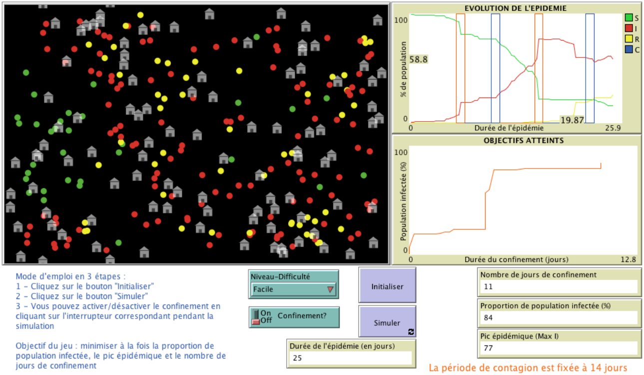
- Agent-based simulations on vaccine effectiveness
- Public trust in vaccines
- In the continuity of CoVprehension
- With the help of Pierrick Tranouez (Litis, University of Rouen Normandie)

Epidemic simulations - Mathematical models

$$S \xrightarrow{P(I)} I \xrightarrow{P(R)} R$$



Epidemic simulations - Agent-based models



https://covprehension.org/2020/03/30/q6.html

Epidemic simulations

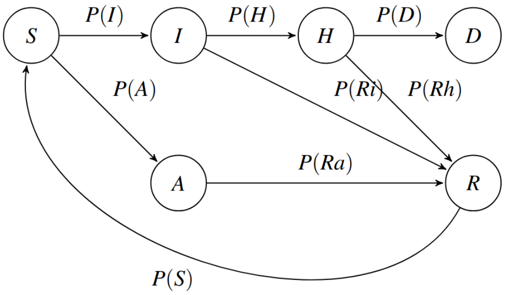
Mathematical models

- Homogeneous
- Macro-level model & analysis

Agent-based models

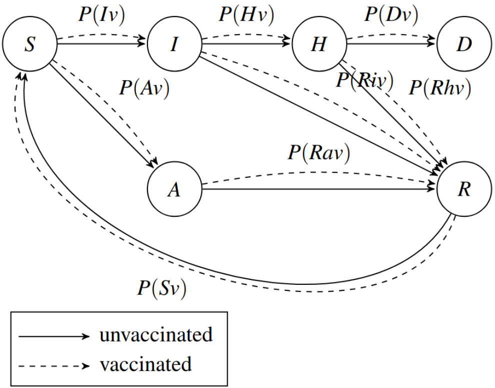
- Heterogeneous
- Micro-level model
- Macro-level analysis

Compartmental model



S: Susceptible; I: Symptomatic; A: Asymptomatic; H: Hospitalised; R: Recovered; D: Deceased

Compartmental model with vaccination



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Compartmental model probabilities

x : *virus dangerousness*

$$P(T) = 1/2 * x$$
$$P(I) = 1 - P(A)$$
$$P(A) = P(T) + 1/4 * (1 - x)$$
$$P(H) = 7/10 * x + i$$
$$P(D) = 1/2 * x + h$$
$$P(Ri) = 1 - P(H)$$
$$P(Rh) = 1 - P(D)$$
$$P(Ra) = a$$
$$P(S) = 1/2 * x + r$$

y : *vaccine effectiveness*

$$P(Tv) = P(T) * (1 - y)$$
$$P(Iv) = 1 - P(Av)$$
$$P(Av) = P(A) * y$$
$$P(Hv) = P(H) * (1 - y)$$
$$P(Dv) = P(D) * (1 - y)$$
$$P(Riv) = P(Ri)$$
$$P(Rhv) = P(Rh)$$
$$P(Rav) = P(Ra)$$
$$P(Sv) = P(S) * (1 - y)$$

$$, i \sim \mathcal{N}(21, 1), h \sim \mathcal{N}(10, 3), a \sim \mathcal{N}(15, 2), r \sim \mathcal{N}(6, 1)$$

Agents

Attributes

- Epidemiological state
- Vaccine status (boolean)
- Trust level (float: 0.0 - 1.0)

Behaviour

- Move randomly
- Influence each other's trust
- Symptomatic & Asymptomatic infect Susceptibles only
- Hospitalised are put apart
- Susceptible, Asymptomatic & Recovered visit hospitalised
- Uninfected vaccinate themselves based on their trust level and available doses

Trust and agent interactions (1/3)

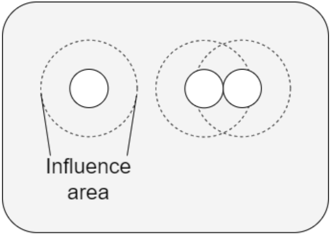


Figure 1: Interpersonal influence - Agents close enough to each other will influence each other's trust. On the right, two agents are close enough to update their trust levels between themselves.

Trust and agent interactions (2/3)

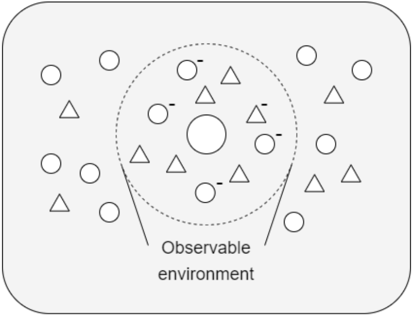


Figure 2: Observational influence - Agents will observe their environment and update their own trust level based on their observations. The observing agent (big circle) can see four unvaccinated agents (small circles) with symptoms (-), five vaccinated agents (small triangles) without symptoms and one vaccinated agent with symptoms.

Trust and agent interactions (3/3)

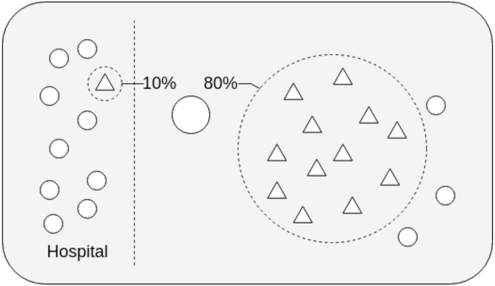


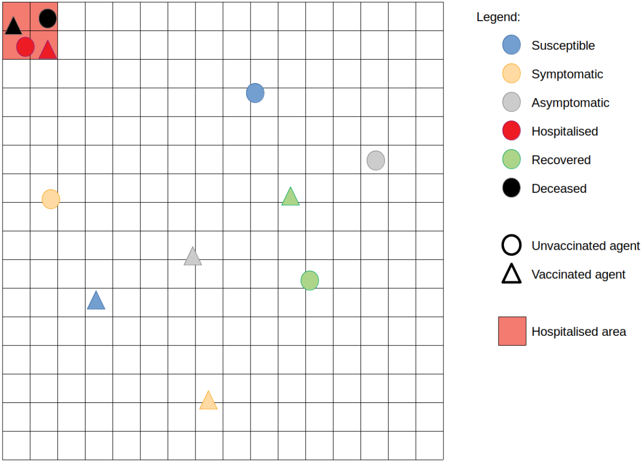
Figure 3: Institutional influence - Agents will receive information about the proportion of vaccinated agents in and out of a specific epidemiological state. The aware agent (big circle) is informed that 10% of hospitalised agents are vaccinated and that 80% of unhospitalised agents are vaccinated.

1. Introduction
2. State-of-the-art
3. Conceptual model
4. **Implementation**
5. Observations
6. Discussion

Details

- NetLogo
- ~800 lines
- Based on CoVprehension's Q17
- Available on GitHub & CoVprehension

Simulation environment



Environment details

- 2000 agents
- Agents initialised unvaccinated
- Agents initialised in the Susceptible class
- One agent initialised in the Symptomatic class
- Trust initialised randomly following custom law

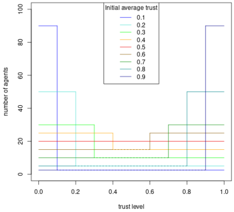
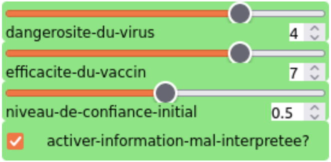


Figure 4: Output of the algorithm used in the initialisation of the population's average trust.

Inputs

- Virus dangerousness (1 - 5)
- Vaccine effectiveness (1 - 9)
- Population average initial trust (0.1 - 0.9)
- Population misinterpretation of information (false/true)



Outputs

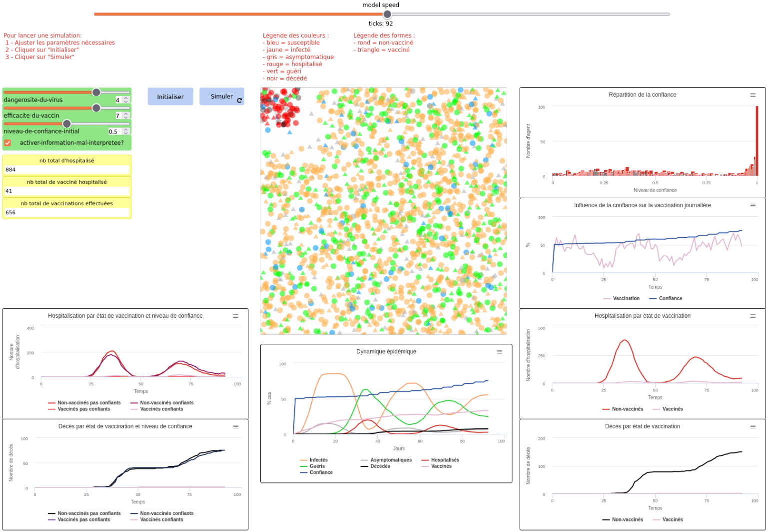
Raw numbers

- Total number of Hospitalised
- Total number of Hospitalised and vaccinated
- Total number of vaccines given

Graphs

- Epidemic dynamic
- Trust distribution
- Trust influence over daily vaccinations
- Hospitalisations and deaths per vaccination status
- Hospitalisations and deaths per vaccination status and trust level

Layout


model speed
ticks: 92
Pour lancer une simulation:
1 - Ajuster les paramètres nécessaires
2 - Cliquer sur "Initialiser"
3 - Cliquer sur "Simuler"
Légende des couleurs :
- bleu = susceptible
- jaune = infecté
- gris = asymptomatique
- rouge = hospitalisé
- vert = guéri
- noir = décédé
Légende des formes :
- rond = non-vacciné
- triangle = vacciné
dangerosite-du-virus 4
efficacite-du-vaccin 7
niveau-de-confiance-initial 0.5
activer-information-mal-interpretee?
Initialiser
Simuler
nb total d'hospitalisé
884
nb total de vacciné hospitalisé
41
nb total de vaccinations effectuées
656
Répartition de la confiance
Nombre d'agent
Niveau de confiance
Influence de la confiance sur la vaccination journalière
Temps
Vaccination
Confiance
Hospitalisation par état de vaccination et niveau de confiance
Nombre d'hospitalisation
Non-vaccinés pas confiants
Non-vaccinés confiants
Vaccinés pas confiants
Vaccinés confiants
Dynamique épidémique
% cas
Jours
Infectés
Guéris
Confiance
Asymptomatiques
Décédés
Hospitalisés
Vaccinés
Hospitalisation par état de vaccination
Nombre d'hospitalisation
Non-vaccinés
Vaccinés
Décès par état de vaccination et niveau de confiance
Nombre de décès
Décès par état de vaccination
Nombre de décès

Population initial trust

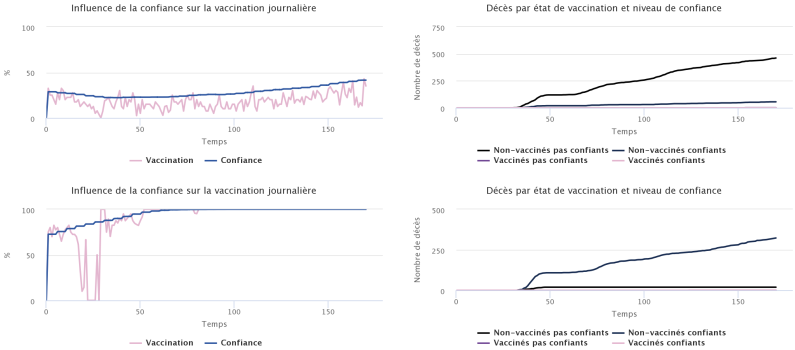


Figure 5: A high initial trust (bottom: 0.7) and an effective vaccine heightens population trust and results in almost two times less deaths than starting with a low population trust (top: 0.3).

Misinterpretation of information

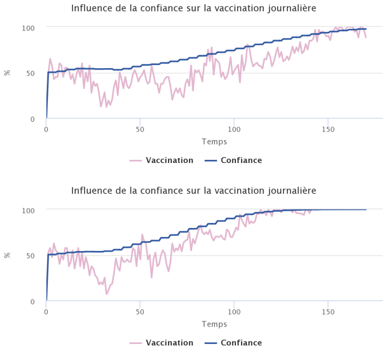


Figure 6: The population trust increases faster **without** misinterpretation of information (bottom), which maximises daily vaccination rates earlier than **with** misinterpretation of information (top).

Contribution

- Population trust is important and needed before the start of the vaccination campaign
- Making sure that the population correctly understands given information is crucial to heighten trust and give people the desire to get vaccinated

Future plans

- Add age groups
- Households (influence trust among families)
- Distrust when insufficient available vaccines
- Different types of information sources (influence trust differently)