Agent Based Modelling of risk taking to survive in adverse conditions

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Introduction

In this study, we investigated how well the agents with conservative or open-mindedness behaviours compete with each other for food in a simulated environment using NetLogo (Wilensky, 1999), agent-based modelling.

Conservatism is an attitude tending to favour established ideas for example to follow conventional methods with predicted efficiency and risks instead of new methods. In contrast, open-minded individuals are willing to consider new ideas as well as convention ways. They take unprecedented risks to discover and innovates. For example, the first person to eat tomato took the risk to confirm that it is edible rather than poisonous and brings it to every European’s table (Smith, 2001). Before eating the first tomato, that person could not test the tomato toxicity in a lab since it was before the emergence of modern science and technologies. During that period, it could be difficult to prove if a new way is better than conventional ways. In this case, would open-mindedness still be better than conservatism if it is not possible to reliably validate new approaches?

We tried to answer this question using our model which simulate competition for food between conservative and open-minded people, and we hypothesised that the group with open-mindedness trait would thrive and the trait would be passed on after generations when the benefits of new approaches outweigh the risks. They would perform better than conservative people as they are more capable to adapt to changes.

In Mitchell, Bryson and Ingram’s study (2014), they found that information with high degree of uncertainty can help corporation in a specie. Based on their findings, our open-mindedness group would share information that may contain useful and harmful information. They are willing to take the risk from harmful information in order to obtain a bigger benefit from the useful information.

We modified the Čače and Bryson’s model (2007) which showed that altruistic behaviour is adaptive. Our model has two agent types and three kinds of beneficial and harmful food to verify our hypothesis. The conclusion can be drawn that, as a specie, it is worth taking risks to gain extra benefits in order to survive in harsh environment.

Method

In our model that is based on Čače and Bryson’s model (2007), two types of agents ”Believer” and ”Doubter” aim to survive and reproduce in a confined virtual environment.

There are 121 x 121 patches in our virtual world, built by using the software Netlogo. Each patch can be empty or filled with a food type (discussed later). One or more agents may appear on any one patch where they consume food if available. The patch becomes empty as the food is consumed.

When the simulation is set up, the starting number of agents is kept constant at 500 with 1:1 ratio of Believers and Doubters. At the beginning each agent is born at a random location and at random age below a Lifespan limit. Lifespan limit is set at 40 by default. At birth, each agent is provided with random amount of energy with normal distribution having a mean of 18 and variance of 0.9, intrinsic knowledge of consuming normal food and 5% chance of acquiring special knowledge of consuming either super or poisonous food. These foods are explained in the following paragraph.

Both agent types gain energy from consuming three types of food on the spot. Regular, super and poisonous food provides +5, +10 and -30 energy respectively. They are randomly generated at Food Replacement Rate (FRR) at random locations. FRR was kept at 2.4 by default. The chance of occurrence of super and poisonous food are the same, and it is lower than the one of regular food. The replacement rate of super and poison food is kept constant. An agent gives birth to a new agent with the same agent type by chance when it’s energy reaches the Reproduction Energy Threshold (RET). RET was kept at (energy level of) 40 by default. During childbirth, the parent agent will retain 80% of energy and transfer 20% to the newly born child. The other attributes of the child are setup the same way as the other agents which are created at the beginning.

Both Believers and Doubters randomly share their acquired knowledge of consuming

super or poisonous food to neighbouring agents. However, only Believers would ”believe” and acquire the received knowledge to consume super and / or poisonous food, this exhibits open-minded behaviour. In other words, most Doubters exhibits conservative behaviour by “doubting” new knowledge and would only consume the conventional regular food unless they already acquired extra intrinsic knowledge at birth.

Once a simulation starts, as timestep increases by one, agents move in random direction at a fixed distance, their age increases by one and their energy level decreases by one. Agents die when their age reaches the lifespan limit (50 by default) or energy reaches 0.

Due to Believers’ capability and flexibility to consume regular and super food, despite the risk of getting harmed from consuming poisonous food, it was hypothesised that they would best Doubters in the competition for survival when the environment becomes adverse including increase in RET, decrease in FRR and shorter lifespan. In this study, we investigate the effects of these three adverse conditions on the ratio between Believer/Doubter. Only one condition is tested at a time while the other conditions remain constant by default value. The ratio between Believer/Doubter is metrics that indicates if Believer or Doubter is more adaptive to the adverse conditions and dominates the world by having a relatively larger population. It is hypothesised that the ratio between Believer/Doubter would increase as either of the three adverse conditions becomes more severe. This is because Believer can consume super food as the second option to cope with harsh conditions. On the other hand, Doubter is expected outperform Believer when adversity is alleviated or removed as they do not have the risk of getting poisoned and killed. By using Netlogo data collection tools, all the data is obtained from 15 simulations to ensure reliability.

Results and Discussions

It was assumed that Believer has no means of scientifically determining if super or poisonous food were beneficial or harmful, as if they existed before emergence of modern science and technologies. They share information which can contain information regarding on super and poison food consumption. Believers were willing to learn these knowledges and take the risks to consume more energy from any food source for survival.

To validate our hypothesis that Believer are more adaptable than Doubter in adverse conditions, we will discuss changes to ratio of

Believer / Doubter by the effect of varying FRR, lifespan limit and RET.

From Figure 1 presented effects of changes in Food Replacement Rate (FRR) on ratio of Believer/Doubter. Ratio of 0.5 represents 1:1 ratio of Believer and Doubter. Ratio above 0.5 represents higher ratio of Believer to Doubter and vice versa. When FRR decreases, normal food becomes scarcer while regeneration rate of super and poison food remained the same. We can see a pattern that as food replacement

General. This is in line with our hypothesis that

Figure 1 Effects of changes in Food Replacement Rate on ratio of Believer/Doubter

believer cope better with harsh condition of low FRR and conversely Doubter outperformed Believer as environment becomes more favourable.

At FRR 4-9, we can see overall decrease in ratio during the first 20 timestep. This sharp decline indicates decline in Believer population and/or rise in Doubter population. The possible reason is that the Believer’s population growth was hindered by their consumption of poison food which decreases energy. This subsequently decreases their survival rate and reproduction rate. Although they can also consume super food which gives them double the energy from normal food, this was clearly offset by poison food. Meanwhile, Doubter population grew as the normal food was in excess. The decline in Believer population can also be attributed to the normal food replacement mechanism. Normal food was programmed to replace anything on a patch when normal food regeneration is triggered by chance. Therefore, occurrences of super food and poison food became less as the FRR is high. This reduced some Believers’ advantage of consuming super food.

At FRR 3-9, the ratio fluctuates with a range, which is expected in simulations. Doubter went extinct at FRR 2 and Believer never went extinct at the presented range of FRR. The data at FRR 7 and 9 overlap, this suggested that ratio may not further decrease as FRR increases beyond 9.

The ratio increases and eventually reached 1 at FRR 2 after 120 timesteps. Similarly the ratio

Figure 2. Percentage of each Believer types at Food Replacement rate 2.4

remained above 0.5 persistently at FRR 2.4 . Believer dominated Doubter when FRR was 2.4 or lower. This is because Believer had the additional option to consume super food. Moreover, the competition for normal becomes more intense when Believer starting to dominate. This made it more difficult for Doubter to survive. However, Believer population should also be affected by consumption poison food. This can be explained by Figure 2.

Figure 2 showed us the changes in the percentage of each Believer types out of the total Believer population at Food Replacement rate 2.4. The proportion of Believer who only eat normal food and super food (blue) remained high, this is followed by the proportion of Believer who eat all food types (orange). The proportion of Believer (red) who eat poison and normal food remained low at all time. This pattern was also observed in other FRR values, but not presented here.

The Believer who eats poison and normal food were the least adaptive agent type, hence their population remained low. In contrast, the other 2 Believer types are fitter as they can consume super food. This helps to explain why Believer population dominated at FRR 2 and 2.4 .

Figure 3a and 4 showed similar results to Figure 1. In Figure 3a showed changes to the ratio of Believer/Doubter when lifespan limit ranges from 20 to 80. The life of an agent becomes shorter lifespan value is smaller. It is

Figure 3a. Effects of changes in Lifespan on ratio of Believer/Doubter

Figure 3b . Time taken for ratio of Believer/Doubter to reach 80% as lifespan increases from 20 to 35

worth mentioned that an agent is given a random age from 0 to lifespan limit at birth. Low lifespan limits an agent’s time to reproduce which subsequently limit population growth. Believer population sustained in the harshest condition when lifespan was set to 20 and 30. At lifepan 20, ratio the increases becomes 1 around timestep of 10 as doubter became extinct. Doubter population remained low (ratio > 0.8) at lifespan 30. This is because short lifespan limits Doubter’s time to gain enough energy from normal food in order to surpass the RET and reproduce. On the other hand, Believer was able to surpass the RET by boosting their energy with consumption of both normal food and super food by chance. Figure 3b provided further evidence that decreasing lifespan from 35 to 20 favours the dominance of Believer. There was a statistically significant difference across the lifespan range of 20-35 as determined by one-way ANOVA (F(3,36) = 89.02326, p < .00001). These observations

agree with our hypothesis that harsh condition favoured Believer.

As lifespan increases from 40 to 80, neither Believer nor Doubter showed clear dominance over each other as the ratio fluctuate around 0.3 to 0.7 persistently. This suggested that

Figure 4. Effects of changes in Reproduction Energy Threshold on ratio of Believer/Doubter

lifespan limit does not influence the ratio of Believer / Doubter, as it increases beyond 40. Because lifespan limit is no longer the limiting factor for both agents’ population growth.

Figure 4 showed the changes of ratio of Believer/Doubter as RET increases. RET is the energy required to reproduce. It is more difficult to reproduce as RET increases during an agent’s lifetime. We can see that higher

RET favors dominance of Believer. When RET is 80, Believer gained total dominance as Doubter became extinct. Similarly, Believer dominance is observed at RET 60 and 70 as the ratio fluctuates above 0.5 . Similar to observation in Figure 3a, at RET 20 to 50, ratio fluctuate around 30 to 70 persistently. This suggested that RET does not influence the ratio of Believer / Doubter, as it decreases beyond 50. Because RET is no longer the limiting factor for both agents’ population growth.

From Figure 1,3 and 4, results showed that Believer population sustained in all conditions. When the three tested conditions became extremely adverse, Believer achieved total dominance while Doubter became extinct. This corresponds with our hypothesis. FRR is the only conditions that showed Doubter’s dominance becoming greater when the condition became more favourable for all agents.

Overall, the results suggested that Believer who are more openminded are more adaptive to adverse conditions. They have tendency acquire new knowledges to consume normal food and special compared to Doubters who only eat conventional normal food. Although Believers have the chance to consume super (+10 energy) which provides double energy than normal food, they also had to take the big risk of consuming poison which deduct 30 energy. The trait of open-mindedness was shown to be beneficial for the survival of the Believer specie although the less adaptive Believer subgroup (the ones only eat poison and normal food) were eliminated at the beginning. Besides Believer presented characteristics of altruism as they promote information sharing, which might be key of their success. Čače and Bryson also suggested that altruistic behaviour of sharing useful information can increase a species’ survival chance (Čače and Bryson, 2007).

The Believers that only eat poison and normal food almost extinct in all simulations. However, harmful information on how poison consumption somehow endured and was circulated by Believers, instead of being gradually lost through generations, like how less adaptive genes were lost in evolution (Albalat, Cañestro, 2016). This corresponds to Mitchell, Bryson and Ingram’s study (Mitchell, Bryson and Ingram, 2014). They found that information with high degree of uncertainty can help corporation and perhaps survival in a specie. They also suggested that socially learned information that may contain error may outperform experience-based learning. Therefore, relying on Believer’s information may contain beneficial and / or harmful knowledge may be more beneficial than relying on well established knowledge alone. Besides, this risking taking behaviour can be observed in human (Kempson et al. 2003) and animals (Wilson et al. 2018).

Conclusion

Using agent based modelling, we showed that specie with open-mindedness is more adaptive than conservative specie to adverse conditions. The study also suggested altruism behaviour, which involves sharing of useful information that carried with uncertainty, can be beneficial for survival of a specie. Future work can be done to test the effect of varying energy provided by super food and poison food on Believers’ survival.

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