Applied & Educational Psychology (2021)
Clausius Scientific Press, Canada

DOI: 10.23977/appep.2021.020111
ISSN 2523-5842 Vol. 2 Num. 1

Human Factors in the Evolution of Emerging Viruses

Jingkai Fu[1], Samuel Choi[2], Ao Tian[3], Zhikai Wang[4], Junzheng Wang[5], Kaiyi Chen[6]

1.Peddie School, Hightstown, NJ, 08520, United States

2. Taft School, Watertown, CT, 06795, United States

3. St. Mark's School, Southborough, MA, 01772, United States

4. Kent School, Kent, CT, 06757, United States

5. Westminster School, Simsbury, CT, 06070, United States

6. Phillips Exeter Academy, Exeter, Nh, 03833, United States

Keywords: Sars-cov-2, Covid-19, Ebola virus

Abstract: This paper compared cultural and political factors in the cases of the Ebola virus and SARS-CoV-2 and demonstrated that, since humans dominate the world, their decisions have tremendous impacts on natural selection and, as the society progresses, more evolutionarily successful viruses will emerge.

1. Introduction

1.1 Overview of Biological Aspects in Viral Evolution

Viruses are characterized as highly mutable biological entities. Unviable on their own, these small microbes utilize other organisms' translation machinery to produce protein. Viruses are the basic embodiment of genetic carriers, with the only goal of producing more copies of itself. They are classified by their morphology and chemical composition. There are two types of morphology: helical and icosahedral. Viruses with helical morphology, such as the tobacco mosaic virus, are composed of a single protein subunit wrapped around nucleic acid to form a helical structure. Viruses with icosahedral morphology spread to the environment and release virion when lyses. Enveloped virus consists of a lipid bilayer membrane covering the protein, which is formed when the virus exits the host cell[1]. Examples of enveloped (or spherical virus) include influenza and coronavirus. Viruses such as bacteriophage can have more complex structure, yet because they do not affect human society, they will not be focused on in this essay. The genetic material can be DNA or RNA based, single-stranded or double-stranded, and segmented or unimolecular. These differences all serve the same purpose: reproduction. Viruses with different morphology have different advantages, and our society is favoring a certain type. For a successful population to develop, individuals must undergo mutations that cause favorable traits to adapt to their environment. A fitting mutation helps the growth of the population, and a large population size increases mutation rates, creating an ever-evolving development cycle.

1.2 Advantageous Mutations

Genetic diversity is the source of evolution. Two major pathways that are taken by viruses to achieve high diversity are through mutation and recombination[2]. Mutation is considered a minor, more subtle genetic change that viruses incorporate to create diversity. Both DNA and RNA viruses must be replicated with the host cell genome. In eukaryotic cells, the DNA repair system reduces replication errors, which reflects a lower mutation rate for DNA based viruses. On the other hand, the structure of RNA is relatively unstable: the 2'-hydroxyl group creates a structure more susceptible to hydrolysis, which creates single-stranded breaks that increase mutation rates by creating locus where RNA segments can bind to.

A large genomic scale plays a crucial role in determining recombination frequencies. A higher recombination frequency allows two independent viral strains that affect the same cell to exchange genetic information and produce novel viral progeny, containing genetic information of both parents. A large genomic scale can come in various forms. For viruses composed of segmented genomes, recombination by independent assortment can take place where the progeny carries different genome segments from distincted parents. This phenomenon is found to have yielded major genetic change in influenza, which has a frequency of recombination of 6 to 10 percent, that allows animal-strain virus to affect humans, resulting in a spillover event.

Viruses and our immune system are continually fighting against each other for survival. After the virus enters the body, the first line of defense they will face is the innate response, including dendritic cells and macrophages and other attack cells. Dendritic cells and macrophages have toll-like receptors such as TLR 3, which identifies ds RNA, TLR 7, which identifies viral ss RNA, and TLR 9, which identifies CPG containing DNA. After those detecting cells identify viral genetic material, they will activate T cells, which will then activate B cells. DNA viruses and RNA viruses have different strategies to avoid our immune system. DNA viruses, which have hundreds of genes, focus on "camouflage and sabotage", possessing complex molecules that have evolved to disrupt defense mechanisms in the body. RNA viruses on the other hand, don't have such intricate molecules. They avoid the immune system by "speed and shape change" due to their high mutation rate. They could evolve in the host cell to become more persistent to the immune system. There haven't been researches determining the mechanism of escaping through speed, but there are studies that use Lymphocytic Choriomeningitis Virus, a small RNA-based virus, to prove that RNA viruses use speed to escape immune defenses.

It's undeniable that genes need to constantly evolve and change in order to survive, but maintaining their stability is also important, which is achieved through accurate mechanisms of replication, as well as DNA repair when there's an accidental lesion of the genetic information. The importance of DNA repair was shown by the investment of making DNA repair enzymes inside the cells, which consists of several percent of the coding capacity. There are two common pathways for DNA repair: base excision and nucleotide excision. In base excision, the altered base is removed by DNA glycosylase, which can identify bases needed to be removed. The second pathway is nucleotide excision, which uses a multienzyme complex to scan for a major distortion in the DNA.

1.3 Lethality or Transmittance

Viruses have a very unique form that they need in a host to survive. A fundamental principle of viral evolution is that viruses must spread from host to host in order to keep them alive and function. If a lethal virus eradicates its host before biosynthesis and maturation, the virus loses its reproductive machinery. Their goal is to infect as many host cells as they can, meanwhile avoiding complications that may result in hosts' death. Usually viruses cause death as a result of a body's hyper immune response to the pathogen: mucus accumulation causes pneumonia, Cytokine storm and fever causes random elimination of body cells. Viruses such as SARS-CoV-2 have a really high transmission rate and a long incubation period. In order to propagate themselves, the viruses need to prevent killing their host for viruses cannot successfully reproduce on lifeless cells. In addition, immobile carriers do not aid transmissions. Lethality seems less important compared to the transmission rate at the start of the stage.

A successful virus doesn't have to be lethal, but it has to be widely spread, such as influenza virus. In 2019 to 2020, there're about 39 million to 56 million people affected by influenza virus in the United States, but there's only about 24 thousand to 62 thousand people who died from the flu. Even though influenza viruses do not have a really high mortality rate, they are easy to transmit from people to people, and this makes them stay alive the whole time.

On the contrary, viruses that are lethal but have a low transmission rate are difficult to remain in our vision. Ebola is a great example. It has shown mortality rates ranging from 22% to 88%, and the average case fatality rate was 50%. On the other hand, Ebola's transmission rate is not high at all compared to other viruses. One of the potential reasons for that is when these types of high mortality rate viruses appear, governments become well aware of them, and take immediate actions.

2. A Brief Macroeconomic Analysis on Ebola and Estimations for Covid-19

The epicentre of the Ebola outbreak in 2013-2016 was in west Africa, specifically in Guinea, Liberia and Sierra Leone. There were 3814 cases in Guinea, which resulted in 2544 deaths; 10678 cases in Liberia and 4810 deaths; Sierra Leone had the most cases: 14124 cases and 3956 deaths. The overall impact of Ebola in the three epicentre countries was estimated at a total of $2.8 billion, which includes the shocks in 2014-2015 and the long-term effects on projection in 2016. From an estimation previously published, in Guinea, the average GDP growth will be reduced by 3.4% compared to no Ebola scenario over the years 2014-2017. In this time frame, Guinea would experience a loss of around $200-300 million. In Liberia, the average loss of GDP in 2014-17 was estimated at $180-250 million which translates into an average of 13.7% loss of GDP. In Sierra Leone, the GDP growth rate would reduce 6-8 % and over the same period, the country would lose between $200 to 265 million[3].

One of the first predictions about COVID-19 outbreak was from McKibbin and Fernando[4]. They predicted 7 scenarios, which made different assumptions on the epidemiology of the virus in China and its spread to the rest of the world based on this assumption. The case-fatality rate in China is less than 5% and the attack rate in China is less than 0.01%, and therefore the mortality rate is roughly 0.0005%, which, looking at the assumptions McKibbin made, is closest to the first scenario. However, the closest one is still too far from reality. Furthermore, McKibbin assumes that the virus will be isolated in China in the first scenario, which makes the result of scenario 1 not of much practical value to us. However, in other scenarios the assumed values are all too high, which leads us to another approach done early in the year.

In another study conducted by Barro et al., they used data from Spanish Flu a century ago to find out an "upper bound" for the consequences of the pandemic we're facing right now[5]. During the 1918 Spanish Flu approximately 2.0% of the population of the world died. If we put this into today's scenario, that means 150 million deaths. According to their model a typical country will face a 6% decrease in GDP and 8% decrease in consumption. Real GDP per capita will experience a 10% or more decrease. However, one problem with this study is the inevitable scale-up effect. The population of the world has grown so significantly that we do not know whether this will cause the reality to be more severe than this prediction because of scale-up effect, or less. More population can mean more population density, which causes the virus to be more easily spread.

A third recent report from McKinsey & Company gave out data about a summary of three polls conducted from April to June on global executives. There were 9 scenarios given out as options and 5 of them now look more realistic than others. Each of them is described as: “A3: virus contained, growth returns”, “A1: virus recurrence, with muted recovery”, “A2: virus recurrence, with strong world rebound”, “B1: virus contained, with lower long term growth”, “B2: virus recurrence, with lower long term growth”. In these, A2 was the least popular choice and the top 3 most popular choices are A1, A3 and B1 according to the last survey. In these above-mentioned scenarios, real GDP drop from 2019Q4 to 2020 Q2 will be around -8.9 to -12.6%; GDP growth will be around -7 to 10%, with the exception of A3(-3.5%). Collectively speaking, China has a theoretical possibility of ending up with a positive GDP growth rate in A3, but in all other scenarios China will have a negative GDP growth rate, which holds true for all other countries. In the worst scenarios, the US and Eurozone will not gain its recovery until at least 2025.

Overall, one can expect that SARS-CoV-2, a classical virus with high transmission rate, does more damage to human society than EVD, a typical virus with high lethality rate.

3. Human Factors

The above-mentioned biological trend is, in fact, a mere reflection of the cultural and historical factors of societies which draws the outcome that we witness today. A successful virus desires only to thrive and reproduce; but to society, the changes and responses to the threat are the most valuable experience to advance humanity. Ebola and COVID-19 are listed as the examples to illustrate the point in this essay, but this trend is certainly not limited to these two specific cases.

We must not disregard humanity’s active participation in contending the viruses. Humans are not simple data points in experimental models, but the dominant species on Earth. When the public recognizes a medical crisis, most individuals will take protective measures to ensure their own safety. In the case of COVID-19, some famous actions include social distancing and wearing masks. Besides the citizens, professional ones step up and take the lead in treating patients and searching for treatments to end the pandemic. These efforts to contend the virus are deemed priority; and, the greater the risks are, the more intense such responses are. By displaying significant influence, viruses may set themselves at a disadvantage to spread and reproduce in the wary society, as long as societal regulations persist. While that sounds ideal, in reality, humans do not always have the upper hand. A multitude of factors including cultural and political ones can seriously influence the public response to pandemic and present unexpected obstacles.

3.1 Cultural Factors on the Spread of the Viruses

Traditions are, indisputably, one of the most iconic characters of a culture, where the essential spirit of a civilization lives. Generation after generation, they are passed down in society as a notion of authority. It is interesting to investigate how distinct traditions facilitate or hinder the combat against viruses in a modern setting.

The Ebola crisis exhibited strong regional association, thus the cultural influence on the outbreak is, compared to those of COVID-19, less diverse and complicated to analyze. During the epidemic from 2014-2016, The medical workers had a challenging time to dispose of the bodies. Many fiercely rejected the cremation of the dead, as that is in direct conflict with the traditional burial rituals that are believed to establish connections with the spiritual world and afterlife[6]. The reliance on traditional healing is another significant obstacle in controlling the virus. With the high fatality rate, people viewed hospitals as the ill and ominous places that harness life. Thus, they seek for traditional healers which, unfortunately, not only did not cure the patients but at many occasions facilitated the spreading by implementing therapies including physical, “magical” touches. Though there are many more, these examples are enough to stress how significant cultural influence can be in a pandemic, and render the virus more successful than it should be.

Traditions are the product of past history, and it cannot escape the fate of being obsolete one day. It is a pity to ditch cultural practices; however, for the wellness of people, changes are necessary to progress, and pandemics are one of the forms that the calls for changes may take.

COVID-19, by contrast, is a global pandemic, which means it is harder to identify how specific cultural traits contribute to its prevalence. To clarify, cultures in different regions do have influences on the transmission. In fact, the virus itself is believed to originate from the consumption of wild bats that carry the virus, which is a demonstration of the local cultural belief that these wild animals are great for health. But realizing the serious situation, traditions are more or less suspended to deal with the public health emergency: at many places, large gatherings are prohibited, and festivals are temporarily held off. Clearly, when people understand the presence of a crisis, they are aware of which to choose between life and temporary celebration.

3.2 Communication Technology and Globalization on Determining the "Successful Viruses"

Human progress in communication technology further solidifies the biological trend: the amount of available information is a determining factor of how successful the transmission of a virus would be. In a world so closely connected by the internet and other media, medical tips and cautions can be distributed through the globe in a matter of seconds. Thus, there is not much time for the virus to spread before society recognizes it. Although the treatment and vaccines may take months or even years to develop, as soon as retrieving some key properties (such as ways of transmission and the necessary environment to deactivate it), people can take precautions to guard themselves. Though that is just the first step to end the outbreak, controlling the virus has proven to be always necessary.

The closer association between people also includes governments and organizations. Common threats always trigger a need for some mutual support, regardless of forms. In 2015, the greatest outbreak of Ebola summoned medical workers from all over the globe to treat the patients, which was unimaginable to many just decades ago. During the COVID-19 pandemic, international flights carrying medical supplies, informative posts regarding the pandemic on social media, and financial aids from non-profits to those in dire need of money all deserve tremendous respect. Credit to technology improvement in transportation and communication, these cooperative actions are vital to triumphing over the viruses, especially when encountering the contagious and deadly ones whose potential can be hardly calculated.

3.3 Communication Technology and Globalization on Determining the "Successful Viruses"

However, many incidents have proven that all of the aforementioned analysis would only be solid if further convoluted politics are disregarded. Prompted by potential political disadvantages once disclosing the information of the new coronavirus, Wuhan's initial attempt to conceal the epidemic to prevent public concerns eventually resulted in the disastrous outbreak. As the virus continued to spread, instead of taking precautions, many nations adopted the so-called herd immunity policy, which is essentially the government's irresponsible decision to not aid the citizens in the public health crisis. These suggest the cliché but true saying that viruses are not the ones that defeat people, but the people themselves. There has yet to be a virus so successful to threaten human domination on the globe; however, a pandemic is surely more than sufficient to challenge the existing order and reveal some sporadic pieces of underlying unsightly works that would otherwise be hidden in comfort. To a virus, success means reproduction. But to humanity, a successful virus is the one that stumbles us on the endless forwarding trail, disrupts the flow of our ordinary life, and challenges for changes and reflections.

Ebola has been around Africa for decades, and there have been several major regional outbreaks. They belong to distinct lineages of viruses and have some nuances in structures. Yet the virus did not attract much attention globally, and it was not until the most recent outbreak in 2014 that it really pronounced itself to the world through the media as a deadly virus. WHO has failed to recognize the harm early on to ensure an advantage in combating the virus, nor did the domestic governments communicate the crisis effectively with the public. Same thing happens with COVID in China: fear of political loss, the local government officials initially attempted to disguise the situation and pacify the public, which ended up in a devastating outbreak considering the high transmission rate of the virus. Both COVID-19 and Ebola Disease have an incubation period, and COVID-19 patients may even be asymptomatic, showing no obvious signs of contracting the virus at all. Such characteristics grant SARS-CoV-2 an advantage when spreading in the population; when people fail to recognize the virus, it is hard to take actions accordingly. A significant difference between SARS-CoV-2 and Ebola is that Ebola can only transmit once symptoms are developed, while SARS-CoV-2 does not have such limitations. Furthermore, SARS-CoV-2 can spread by both contact and droplets while Ebola is only transmitted through direct contact. Such properties undoubtedly made SARS-CoV-2 a more contagious and impactful virus than Ebola.

Even after SAR-CoV-2 has shown its horrific nature, it is frustrating to see many governments still deem politics more important than fighting the virus. The most notable example is in the US, when everything hauls to make a path for the party benefits and the next national election. Indeed, this is a significant event, yet the life and property of the citizens shall not be sacrifices of such strife. To maintain a high support rate, politicians relentlessly attack each other and advocate their ideas to the followers, which includes many reckless or reluctant proposals. For instance, the Trump administration rushed to restart the economy after a temporary lockdown, as people without income were protesting. However, such could never be good news to control the pandemic. The political atmosphere in America also hinders the containment of the virus. Too many individuals have been unwilling to wear masks and practice social-distancing, and their irresponsible behaviour in the name of liberty eventually hurt the entire community. Freedom is not an excuse to counter the common effort in defeating the virus. SARS-CoV-2 is a successful virus to disclose all of such hidden conflicts, and how incompatible political campaigns are in dealing with a public health crisis. Though politicians frequently voice themselves regarding different topics, they are not omnipotent saints. Public health emergencies require not political ideology but the dedicated effort of medical workers and their authentic suggestions to solve.

By allowing the political interests to overshadow the public wellness, politicians definitely undermine tons of hard work of scientists and medical professionals. Though some realize the urgency and seriousness, to those who are already severely impacted by the virus, the realization may come too late. People expect governments to be competent, for they are where the trust of the public lies; yet recounting the current situation around the globe, in many places and fields humans have hardly acted as a unit to battle the viruses. Society must not expect the virus to disappear magically. Everyone, like they should, need to honor the biological work done by scholars, and the best means to accomplish such is to smother the prejudice against science and cease embracing the irresponsible ideas and behaviors that hurt both individual and public interests. While we render the viruses' biological success futile through medical research, we should also always keep in mind that in a global public health crisis, our common enemy is not foreigners, the poor, or patients, but the virus. On this note, a pandemic is an effective reminder that the biological success of a virus is not only attributed to the species itself, but also man's arrogance and animosity in response. Hopefully, at a great cost, society is able to learn and redirect itself on the way of advancing humanity to greater good in the eternal social cycle.

4. Human Factors

In this paper we first presented a biological trend that has been a classical epidemiological assumption. Then we introduced evolution theory and the "goal" virus, which is not necessarily to max out lethality but to thrive. In an example that compares two recent outbreaks, we've shown that a more communicable virus both has more economic impact on humans and achieves its goal of living longer. Afterwards, we reasoned that because of natural selection, cultural and political factors in human society have caused such a biological trend to some extent. Therefore, much of the damage the viruses bring is actually caused by people themselves.

In the future studies on economy and viruses, it is important to consider the relationship between men and viruses not as simply independent variable to dependent variable. Our current behavior "chooses" our future virus, and our future virus shapes our behavior in the future and so on. To conduct any research on communicable viral diseases, considering possible mutation of the virus should be a necessity. Though predicting mutation seems too remote from us, interestingly enough though, we seem to have the technology to predict viral mutations using neural networks with an accuracy of 75%. (Salama, et al., 2016) Once this algorithm is optimized and a higher accuracy attained, we should probably consider a new viral epidemiologic model with predicting viral mutations as part of the equation. This is one big step forward towards the problem of viral diseases we have right now. It will be as revolutionary as when the vaccine first came out.

References

[1] Louten, Jennifer(2016). Virus Structure and Classification. Essential Human Virology, pp: 19-29.

[2] Fleischmann, W. Robert(1996). Medical Microbiology, 4th ed., Ch. 43

[3] UNDP(2015). Socio-Economic Impact of Ebola Virus Disease in West African Countries. pp: 6-67.

[4] McKibbin, Warwick J. and Fernando, Roshen(2020). The Global Macroeconomic Impacts of COVID-19: Seven Scenarios. Asian Economic Papers(2021) vol. 20, no. 2, pp: 1–30.

[5] Barro, Robert J., Ursua, José F., Weng, Joanna(2020). The Coronavirus and the Great Influenza Epidemic - Lessons from the 'Spanish Flu' for the Coronavirus's Potential Effects on Mortality and Economic Activity. CESifo Working Paper No. 8166

[6] Manguvo, Angellar, and Benford Mafuvadze(2015). "The Impact of Traditional and Religious Practices on the Spread of Ebola in West Africa: Time for a Strategic Shift." The Pan African Medical Journal, vol. 22(suppl. 1): 9

[7] Salama, M.A., Hassanien, A.E. & Mostafa, A.(2016). The prediction of virus mutation using neural networks and rough set techniques. J Bioinform Sys Biology vol.2016, issue 1, no. 10.