TECHNOLOGICAL HOMEOSTASIS OF CHILDHOOD VACCINATION IN THE UNITED STATES

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By

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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In the mid-20th century, the lesser-known American microbiologist Maurice Hilleman developed more than 40 vaccines for diseases such as measles, mumps, rubella, hepatitis A, and hepatitis B (Newman, 2005). The steps Hilleman took to advance vaccine technology improved the availability of vaccines and saved millions of lives. As vaccine technology spread around the world, vaccination became commonplace in developed countries. The prevalence of vaccines in these countries should allow almost all members of these populations to become vaccinated. However, resistance to vaccination has been observed since the first instances of inoculation in the mid-18th century (Hoffman, 2019; Kirkpatrick, 2016) and is growing in popularity in the present day.

Vaccine resistance in developed countries is in direct contrast with vaccine receptivity in underdeveloped countries. Unfortunately, for many diseases that are prevalent in underdeveloped countries, vaccines do not exist or are inaccessible. Malaria, for example, is a complex and serious disease without a highly efficacious cure. Some countries are improving preventive measures against malaria via increased use of insecticidal nests, indoor residual spraying, and better diagnostics (World Health Organization, 2019a). Countries in sub-Saharan Africa, with an average poverty rate of 41% (Patel, 2018) have observed upticks in malaria cases due to their inability to improve preventive measures against the disease.

To reduce the number of malaria cases in sub-Saharan Africa, the pharmaceutical company GlaxoSmithKline (GSK) has recently developed and is distributing a vaccine called Mosquirix. Mosquirix is produced by growing the RTS,S protein in *Saccharomyces cerevisiae* yeast cells (Wilde & Cohen, 1999). The technical project involves the design of a manufacturing plant for the production of the RTS,S protein to contribute to malaria eradication in sub-Saharan

Africa. The technical team aims to lower the cost of the drug while also ensuring profitability by incorporating single use systems into the manufacturing process.

The technical and STS topics are tightly coupled due to the inherent juxtaposition between the need/desire for vaccines in impoverished regions of sub-Saharan Africa and the technological homeostasis that antivaccination attitudes have caused in developed countries such as the United States. There is an interesting contrast between vaccination attitudes in countries where disease runs rampant and countries where public health is controlled via legislation.

ANALYSIS OF THE ADOPTION OF VACCINE TECHNOLOGY

Roger's theory of Diffusion of Innovations, wherein technology goes through a series of adopters that are normally distributed over time, is a theory that can be loosely extended to the Antivax Movement. Vaccines likely went through the innovator, early adopter, and early majority phases in accordance with the theory of Diffusion of Innovations. However, instead of continuing to increase the number of adopters during the late majority and laggard phases, adoption of vaccines reached a technological homeostasis. The stagnation or even regression of the number of adopters has led scientists and medical doctors to describe the Antivax Movement as some variant of "a regression in modern medicine" (Hussain et al., 2018, title).

Law and Callon's Actor-Network Theory (Law & Callon, 1988) can be used in addition to Roger's Diffusion of Innovations to analyze the Antivax Movement. It is important to realize one-way and two-way interactions between actors in the movement in order to incite change, either by improving or discontinuing communication between certain stakeholders. Figure 1, found on the following page, shows the connections between many of the relevant actors in the antivax movement. These actors can be placed into three primary categories: human, structural, and natural. The distinction between these actors is important because structural actors are not easily influenced and natural actors are almost impossible to influence. However, through improved understanding of the motivations, interactions, and ethics of each actor, one or more *human* stakeholders can generate a solution to the antivax problem.

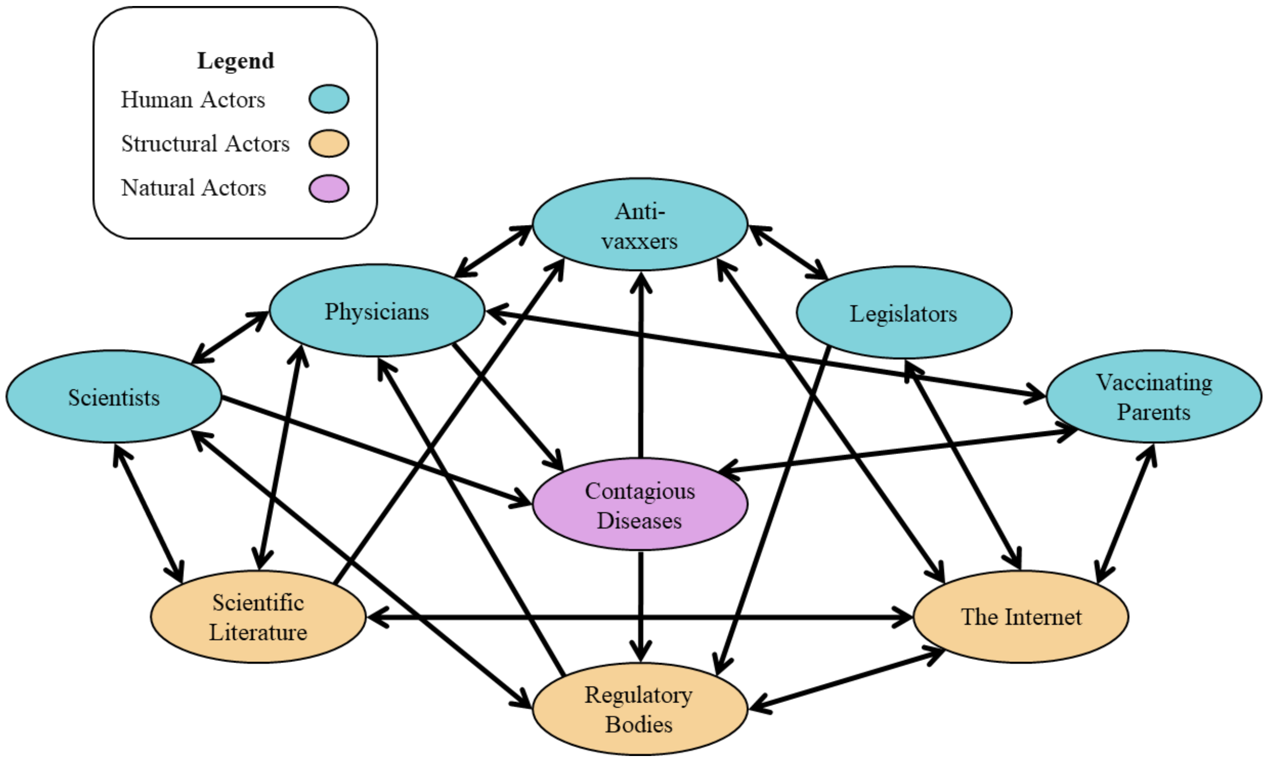

Figure 1: Relevant Actors in the anti-vax movement from an Actor-Network Theory perspective (Clore, 2020b)

SHORTCOMINGS OF HERD IMMUNITY

Those who are resistant to vaccinations or refuse to vaccinate pose a significant threat to public health. These people, colloquially called "Antivaxxers," have caused decreases in vaccination rates, which have in turn improved disease proliferation. Given the highly contagious nature of many viral diseases, vaccination rates in the range of 96% - 99% are often required for adequate herd immunity (Hussain et al., 2018). Herd immunity is the concept of vaccinating the greatest possible proportion of a population in order to limit the spread of disease (Watson, 2018). When enough members of a population are vaccinated, a disease has a very limited chance of spreading because it faces two significant challenges: it cannot find an initial host to infect, and then cannot find successive hosts in order to proliferate the disease. For these reasons, herd immunity helps protect the immunocompromised, who are medically unable to receive vaccines.

If you imagine vaccination as a probabilistic game, there are four possible outcomes: vaccinate and get infected, vaccinate and remain well, refuse to vaccinate and get infected, or refuse to vaccinate and remain well. It should be obvious that the optimal outcome will include remaining well, but which vaccination choice best accomplishes this? Table 1 helps illustrate that vaccination leads to the greatest chance of remaining well.

Table 1: Importance of herd immunity in the sample space for infection versus vaccination (Clore, 2020a)

	Vaccinated	**Unvaccinated**
Infected	Incomplete protection by vaccine, not protected by herd immunity	No protection by vaccine, not protected by herd immunity
Uninfected	Protected by vaccine, protected by herd immunity	No protection by vaccine, protected by herd immunity

Those who remain uninfected as a disease spreads are protected by herd immunity, regardless of whether or not they are vaccinated. Similarly, those who are vaccinated should be protected by their vaccine. Unfortunately, protection is not completely guaranteed from either vaccination or herd immunity. Vaccines have between a 1% and 5% chance of not leading to immunity, but this can be easily combated with a second dose of the vaccine (CDC, 2015).

While disease immunity can be attained with one or more doses of vaccines and tested with blood titers, there is no reliable way to ensure effective herd immunity. Considering that medical records are private, individual members of society have no way of knowing what proportion of the people around them are vaccinated. Without this knowledge, the effectiveness of herd immunity cannot be adequately determined; the risks of infection without a vaccine should be deemed greater than the risks of infection with a vaccine.

Vaccination combines protection from a vaccine with protection via herd immunity, while a lack of vaccination relies solely on potentially insufficient herd immunity. Additionally, personal refusal to vaccinate inherently decreases the effectiveness of herd immunity. Thus, the likelihood of remaining uninfected after receiving vaccinations is greater than the likelihood of remaining uninfected without a vaccine.

CONFLICT BETWEEN AUTONOMY AND BEST INTEREST

The claim can be made that parents have a moral, as well as legal, obligation to protect their children's health to the best of their ability. Many conclude from this that parents have a moral and ethical obligation to vaccinate themselves and their children. However, such a conclusion ignores the fact that "sometimes it is really not in a child's best interest to be vaccinated" (Giubilini, 2019, p. 31). Vaccines are known to be associated with a number of side effects, ranging from injection site soreness to anaphylaxis (Giubilini, 2019). Even so, the more severe risks of vaccination, including anaphylaxis and Guillain-Barre Syndrome (GBS), are incredibly unlikely, with approximately one case per million vaccinations (McNeil et al., 2015). But these, or worse, reactions can also occur as a result of infections resulting from vaccine-preventable diseases.

There is a threshold at which the risks of vaccine side effects actually outweigh the risks associated with contracting the infectious disease: a vaccination rate of approximately 99.99% (Giubilini, 2019). To provide an example of the impracticability of a 99.99% vaccination rate, consider the 2017 Measles, Mumps, and Rubella (MMR) vaccination rates in the United States. Statewide vaccination rates ranged from 82.5 to 98.3% (CDC, 2019a). Even in the state with the highest vaccination rate for MMR – Massachusetts at 98.3% – an additional 1.69% of the population would need to be vaccinated for vaccine side effects to take precedence. With a population of approximately 7 million (U.S. Census Bureau, 2019), achieving this rate would require an additional 118,000 vaccinations. Also consider that the threshold for effective herd immunity against MMR is 96% vaccination (Bowes, 2016). This proportion was met or exceeded in only two states, leaving 48 states without effective herd immunity and without good reason to fixate on the risks of vaccination. Thus, it is in the best interest of individuals to get vaccinations and tolerate their potential side effects.

Antivaxxers can be against vaccination for reasons other than concern for side effects. There is a common belief that vaccines are not necessary for diseases that have been deemed eliminated. As an expert in infectious disease at the Children's Hospital of Philadelphia, Dr. Paul Offit believes that "vaccines are a victim of their own success," (Hoffman, 2019, para. 14). By this, he means that the uncomfortable and deadly symptoms of diseases have been suppressed or forgotten as a result of eradication with vaccinations. This lack of memory has convinced antivaxxers that vaccination is not necessary. Especially for uninsured Americans, who numbered 27.9 million in 2018 (Tolbert et al., 2019), it can seem unnecessary to pay large out-of-pocket costs for a seemingly eradicated disease.

Individuals aspire to be autonomous and make independent and cost-effective decisions. This leads to the concept of excludability, which dictates whether or not consumers can have access to a good or service without paying for it. Herd immunity can be considered non-excludable; that is, individuals can easily benefit from it without contributing to it. This is good for the uninsured, but unfortunately leads to a "free-riding problem," wherein members of society do not have an incentive to contribute to herd immunity but reap its benefits all the same (Giubilini, 2019, p. 21). This can be related to William Forster Lloyd's Tragedy of the Commons, which describes a system that is common to all, but has a carrying capacity at which the system is exhausted (Hardin, 1968). Each member of the system can choose whether to use the system or abuse the system. If too many people abuse the system, the "tragedy" occurs, and the success of the system is ruined (Hardin, 1968).

In the case of vaccination, herd immunity represents the commons: there is some safety from disease as long as enough members of the system vaccinate. The tragedy comes about when members of the system believe they can take advantage of the commons without contributing their own vaccination to it. Herd immunity becomes ineffective and diseases can spread more easily through the system; the public good that herd immunity provides becomes compromised.

ETHICS OF VACCINE LEGISLATION

There are three primary ethical theories that can be applied to the antivax movement. These include Duty ethics, Rights ethics, and Utilitarianism. Immanuel Kant's duty ethics, which states that all specific duties derive from a fundamental duty to respect others (Kant, 1998), lends itself to the argument that legislators have a duty to "promote the general Welfare" in accordance with the preamble to the United States Constitution. This implies a duty to enhance public health, which is best accomplished by legislative guidance or laws. Because passing a law to force vaccination is itself unethical, lawmakers have instead passed legislation to prevent medically-able children from attending school if their vaccinations are not up to date. When the majority of unvaccinated children are not permitted to attend school, other schoolchildren, including the medically exempt, are safer. Working parents, who do not wish to homeschool their children, are often compelled by this legislation to vaccinate their children.

In addition to the duty test, legislators also use the utilitarian ethics test when they choose to uphold public health over religious freedom. John Stuart Mill's concept of Utility was originally intended to evaluate ethics surrounding the happiness of individuals, but it can be extended to address the "happiness," or health, of society at large (Schefczyk, n.d.). Vaccination leads to herd immunity, which contributes to greater societal health. Thus, from a utilitarian viewpoint, utility is maximized when members of society are vaccinated. Thus, legislators keep people safe through the passage of vaccine legislation with the consequence of hindrances to religious expression.

When the government modifies or eliminates religious exemptions, the affected stakeholders can use rights ethics to justify their opposition to the legislation. The United States Constitution protects certain rights of individuals. Especially relevant in this case is the right to freely exercise religion. Broadly, freedom of religion should allow individuals to express their religious beliefs however they choose, up to and including the choice for or against vaccination. Legislation that forces vaccination is at odds with free expression of religion. The reactions that religious groups have had to such legislation has varied significantly. When a bill ending nonmedical exemptions to vaccination was being passed in the state of New York, some resistance was observed, but not enough to prevent passage of the bill (Allyn, 2019). Conversely, as a similar bill worked its way through the New Jersey state government, groups of Orthodox Jews vocalized their feelings about government interference in their religious practices enough to prevent passage of the bill (Tully et al., 2020). It is worth noting that Orthodox Jews are not necessarily vaccine deniers or vaccine resisters, but are sensitive to government interference in their religion.

THE PSYCHOLOGY OF VACCINATION

Psychology is a science that attempts to explain human behavior. By using the psychological concepts of egoism, omission bias, and diffusion of responsibility, antivaccination sentiments can be explained.

If rationality is interpreted as decision-making that is objective and logical, it can be said that "rationality…is not what many people rely on to make vaccination decisions," (Giubilini, 2019, p. 16). Since many vaccines are meant to occur during infancy, it is the responsibility of new or otherwise postpartum mothers to make vaccination decisions for their babies. The postpartum period is associated with heightened emotions, including the "baby blues" or other mood disorders (Unity Point Health, 2020). These emotional changes may lead mothers away from rational decision-making and may cause them to decide against vaccination for their babies.

Regardless of emotional state, psychological egoism suggests that people are guided by their own self-interest, which leads them to make vaccination decisions that they perceive will make/keep them the healthiest. For many, vaccines are perceived as an obvious step toward disease prevention. This perception may be based on research into the scientific literature, but it is more likely that parents are able to strongly influence the morals and opinions of their children

(Suttie, 2015). This perpetuates a cycle wherein anti-vax parents bear children who grow up in the culture of vaccine refusal and, as adults, are more likely to condone the anti-vaccination behavior that their parents demonstrated.

An example of medical decisions being guided by self-interest can be related to the 2020 COVID-19 pandemic. States and countries around the world declared states of emergency and encouraged individuals to partake in "social distancing" to slow the spread of the disease (Stevens, 2020). However, the need to feel some sense of control in an unfamiliar and uncertain situation compelled people to leave their homes in a state of panic; they flocked to grocery stores in large numbers to purchase toilet paper, milk, hand sanitizer, bottled water, and pasta in large quantities (Lufkin, 2020).

Young people especially, who are often asymptomatic for the disease but can be vectors for its transmission, continued to visit bars and restaurants, showing blatant disregard for suggestions from scientists and healthcare professionals. This conduct strongly suggests disregard/disrespect for authority, loss aversion, as well as a diffusion of responsibility. To better explain the differences between loss aversion and diffusion of responsibility, Table 2 describes the behavior of others and the resulting reaction in accordance with each psychological principle.

Table 2: Tabular explanations of loss aversion and diffusion of responsibility (Clore, 2020c)

	Other People	**Individual Reaction**
Loss Aversion	Are not acting	"I won't either"
Diffusion of Responsibility	Will act	"I don't need to"

This psychology related to the COVID-19 pandemic offers some striking comparisons to the behaviors of antivaxxers, who also practice both loss aversion and diffusion of responsibility.

Loss aversion among antivaxxers can best be related to economic loss aversion: people would rather not suffer a loss than acquire an equivalent gain. This takes the form of avoiding vaccinations to so that negative side effects are not suffered. The equivalent gain, immunity from disease, is eluded as a result. Socially, this loss aversion is analogous to a fear of missing out; the growth of the Antivax Movement has led to a bandwagon of diffusion of responsibility.

Diffusion of responsibility is the psychological phenomenon whereby an individual assumes that other members of a group will take responsibility for a task or action that needs to be accomplished. As group size increases, inaction increases among members of society. The perception that other people will vaccinate and contribute to herd immunity leads people to the conclusion that they themselves are under no obligation to vaccinate. As a result, vaccination rates decrease and herd immunity becomes less effective.

Omission bias is another psychological principle that plays a strong role in vaccination behavior. Decisions that are affected by omission bias lead people to prefer an inactive or passive response to an active response, even when the negative consequences are the same. The preference for an omission over a commission is determined by the magnitude of guilt or regret that results from the consequence(s) of a decision. From a moral perspective, omissions and commissions are equivalent "when knowledge and intentions are held constant," (Ritov & Baron, 1990, para. 4) and should therefore not lead to imbalanced feelings of guilt.

In a 1990 study, Ritov and Baron found that antivax parents would feel greater guilt if their hypothetical child died of a disease despite receiving a vaccination for it than if the child died after not receiving the vaccine (Ritov & Baron, 1990). Since it is significantly more likely to die from a disease when you are unvaccinated than it is to die from the same disease when you are vaccinated, the two outcomes cannot be equally weighted. Because knowledge of the two circumstances is not constant, the omission and commission are not morally equivalent. Ritov and Baron also posit that regret is felt by the vaccine decision-maker and not those who fall sick. Thus, feelings of regret are a selfish and unethical justification for omission bias.

ELIMINATING ANTI-VACCINATION SENTIMENTS

Vaccine hesitancy is often described as a continuum (Figure 2). While there are many members of society who accept vaccines or accept them hesitantly, there are still more who delay, refuse, or entirely deny vaccines as viable and healthy methods for disease prevention.

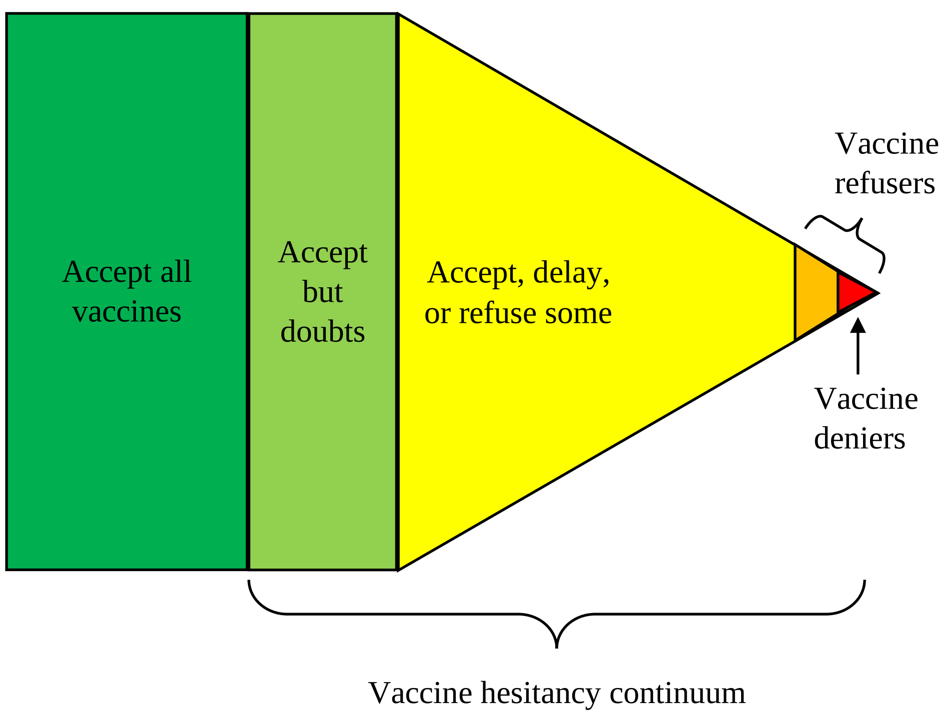

Figure 2: Illustration of the vaccine hesitancy continuum (adapted from Butler, 2017)

Vaccine hesitancy, delay, and refusal are growing global health concerns. To enhance vaccine uptake, and therefore public health, public health officials and legislators must make a coordinated effort to shift perceptions of vaccines to the positive. Officials can accomplish this by improving awareness of the threats of disease, avoiding overstatements of the risks of vaccines, and by improving availability, accessibility, and affordability of vaccines.

Behaviors observed during the COVID-19 pandemic revealed that some legislators and political figures are not inclined to heed the recommendations made by the Centers for Disease Control and Prevention (CDC), regardless of scientific justification. This suggests a need for political figures that are not strongly biased toward medical omissions. Since vaccination is not at the forefront of political campaigns, it can be difficult for the public to elect officials based on this criteria. Fortunately, legislation can be passed to prevent anti-vaxxers from inhabiting certain public spaces, such as schools. This can improve public safety, but is also associated with certain ethical dilemmas regarding the role of the government in the lives of the American people.

Vaccination legislation could be more beneficial if it were proactive instead of preventive. At present, legislation is restrictive for the unvaccinated; it denies them certain rights and alienates them from the United States government. An alternate solution is to pass legislation to make vaccines more widely available, accessible, and affordable. For the more than 28 million uninsured Americans, decreasing the out-of-pocket costs for childhood vaccinations could be an immediate incentive to vaccinate. Recall from Figure 2 that there is a relatively small proportion of people who completely refuse or deny vaccines; most of the hesitancy falls in the “accept, delay, or refuse some” category. For people in this category, the financial considerations for vaccine hesitancy should not be ignored.

It is clear that preventive legislation can provide a short-term solution to the problems associated with the Antivax Movement. However, a better solution is necessary to keep improve global health and public safety in the long-term. Such a solution can only be generated via proactive legislation that comes about when both public health officials and legislators are knowledgeable about the psychology at play and possess the persuasive skills to combat it.

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