Anti-Vaccination: Addressing Vaccine Hesitancy and its Consequences for Modern Public Health Policy

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Abstract

Modern vaccination is arguably the most significant medical achievement in human history. Through widespread vaccination, populations are no longer susceptible to diseases that plagued humanity for most of its existence (measles, rubella, smallpox). While vaccinations have largely shown themselves as safe and efficacious under most circumstances, small but considerable portions of the worldwide population reject vaccination for various social, religious, and political reasons. Research indicates that vaccine hesitancy spans all socioeconomic boundaries, affecting patients and their physicians. To explore the underlying themes of vaccine hesitancy and their relationship to loss aversion and omission bias, a study of various factors underlying resistance to immunization will be undertaken, with community-based and governmental interventions explored as potential remedies to decrease vaccine uptake.

Anti-Vaccination: Addressing Vaccine Hesitancy and its Consequences for Modern Public Health Policy

Since the end of the 18th century, the development and production of vaccines have brought about the most profound reduction in disease and mortality in human history. From Edward Jenner's monumental breakthrough in discovering the first smallpox vaccine to the development of modern mRNA vaccines to combat the COVID-19 pandemic, vaccination technology has played an integral role in advancing modern healthcare and disease prevention. Noted as the most significant public health achievement of the 20th century by the Center for Disease Control, vaccination is second only to clean drinking water as the most important medical achievement of the modern era (Plotkin, 2005).

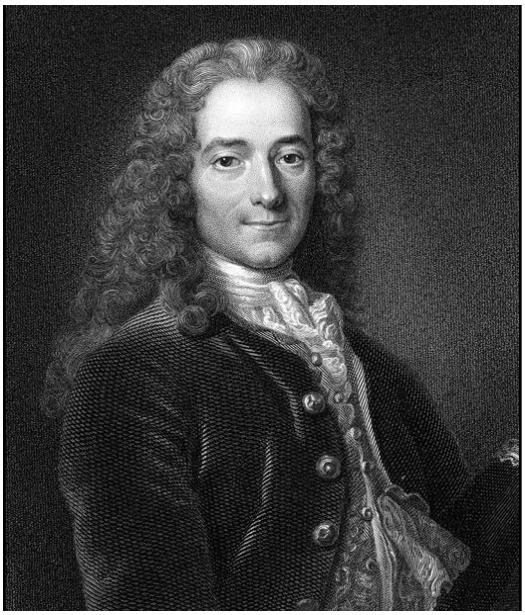
While the effects of widespread vaccination have profoundly impacted human civilization for good, vaccine hesitancy is an issue that has troubled public health officials since the inception of modern vaccination programs. Whether it is parents refusing to vaccinate their children before primary school, individuals opting out due to religious reasons, or the propagation of ill-researched theories regarding the safety and efficacy of common and well-tested vaccines, vaccine hesitancy has become a major stumbling block toward keeping preventable diseases preventable. While doubts regarding the safety and efficacy of modern vaccines may appear to derive from present misgivings with pharmaceutical companies and governmental policies, vaccine hesitancy has been present in American society since its inception. Due to the current debates surrounding various aspects of public health policy, particularly compulsory vaccination, a proper understanding of the cognitive biases and assumptions underlying major groups opposed to vaccinations must be understood to adequately address the issue. Thus, an analysis of various social, political, and religious ideas underlying

vaccine hesitancy in the United States will be conducted to better understand vaccine hesitancy among the American population. Vaccine hesitancy and its relationship to loss aversion and omission bias will also be investigated, with particular emphasis on potential community-based and governmental interventions that could increase vaccine uptake in these groups.

Brief History of Vaccination

Vaccination is a medical achievement that can trace its roots back into prehistory. While modern vaccination techniques were not present in ancient times, an understanding of acquired immunity appears very early in the anthropological record. The first recorded instance of acquired immunity is indirectly attested to in the writings of the French philosopher Voltaire. In his essay, *On Variolation*, Voltaire writes that "[t]he Circassians [a Middle Eastern people] perceived that of a thousand persons hardly one was attacked twice by full-blown smallpox... one never truly has that illness twice in life" (Plotkin, 2005, p. S5). The Greek physician Galen provides another ancient account of acquired immunity. Serving as the court physician for the Roman Emperor Marcus Aurelius during the Antonine Plague, Galen noted that those who had survived the disease incurred large black scabs but did not contract the illness again, observing that they were able to take care of their families without being reinfected (Littman, 1973). These attestations to acquired immunity demonstrate a relatively ancient understanding that some diseases conferred life-long

Figure 1.
Voltaire



Note. Voltaire, the French philosopher and historian. From *Encyclopedia Britannica*, by Encyclopedia Britannica, 2023. https://www.britannica.com/biography/Voltaire/images-videos#/media/1/632488/228411

protection. Knowledge of rudimentary immunology continued to accumulate through the classical age, culminating in the invention of inoculation.

Inoculation, whose name derives from the Latin word *inoculare*, meaning "to graft," is a primitive method of preventing infection by exposing individuals to tiny amounts of an active disease via skin penetration or inhalation (Plotkin, 2005). By the Middle Ages, Chinese physicians took notice of the lack of reinfection among smallpox survivors and introduced variolation, the first known form of intentional inoculation.

While evidence of inoculation in the ancient and medieval world mainly pertains to variolation, historical sources also note that many rulers in the classical world would ingest small doses of poison to prevent future assassination attempts. The most famous example of this is Mithridates, King of Pontus. Mithridates, an enemy of the Roman Republic, reportedly survived multiple threats to his life by regularly drinking a small amount of poison. While the tale of Mithridates' legendary immunity and inoculation of individuals in China may seem sparse and insignificant, both incidents hint at a growing understanding that exposure to a disease in small amounts can prevent deadlier, future infections.

By the beginning of the early modern era, knowledge of variolation had spread to the European continent by way of Lady Mary Wortley Montagu. Montagu, notable for her *Letters from the Ottoman Empire,* first witnessed variolation while on a trip to Constantinople (Flemming, 2020). Observing that variolated individuals did not contract smallpox upon second exposure, Montagu brought this discovery back to Europe, introducing the idea to the United Kingdom (Grundy, 2000). With the introduction of the practice in the United Kingdom and continental Europe, variolation became commonplace, and by the 18th century, physicians

generally agreed that it was an effective medical practice. By the early 1800s, variolation had become the primary method of preventing smallpox before modern vaccination (Riedel, 2005).

Figure 2.
Mithridates VI Eupator

Note. Mithridates was famous for his frequent ingestion of poison. From *Wikimedia Commons*, by Wikipedia, n.d. https://commons.wikimedia.org/wiki/File:Mithridates_VI_Louvre.jpg

While the incidence of variolation is frequently documented in the early modern era, the first extensively written instance of mass inoculation in the western hemisphere comes from the American War for Independence. Since the inception of European colonization in North and South America, smallpox routinely killed or maimed large proportions of the colonial and indigenous populations each year. During the Revolutionary War, this problem persisted, with smallpox being the American troops' leading cause of death (Fenn, 2002). In response to this issue, General George Washington mandated compulsory vaccination of American forces to prevent further outbreaks. Notably, American records indicate that mandatory variolation dampened epidemics overall but caused notable side effects, such as severe illness and death due to exposure to too much viral matter. Despite its sometimes-deadly side effects, variolation remained the primary form of immunization before the industrial revolution. Still, significant advances in vaccination technology would be made, altering the course of medicine forever.

In the late 18th century, Edward Jenner, a British physician, stumbled upon a discovery that would dramatically alter the course of modern medicine. Regarded as the father of modern immunology, Jenner developed the technique that is now known as vaccination (Riedel, 2005).

Remembering from his childhood that milkmaids never seemed to contract smallpox compared to other farm workers, Jenner hypothesized a link between cowpox, a disease commonly contracted by the milkmaids, and smallpox. To test his hypothesis, in May 1796, Jenner inoculated James Phipps with a fresh cowpox lesion from Sarah Nelms, a local milkmaid. Over ten days, Jenner observed the boy's recovery from cowpox and found that he did not contract smallpox after exposing him to the disease later in the month. From this monumental discovery, Jenner developed a theory that cowpox exposure prevented smallpox infection. Jenner called his discovery "vaccination," deriving the term from *vaccinia*, the Latin word for cowpox.

Jenner's discovery quickly spread across Europe and North America, and by 1840 the United Kingdom prohibited the practice of variolation since vaccination had proven to be a much safer and more effective method. In light of this new discovery, the first vaccination program began in the United States, with President Thomas Jefferson creating the National Vaccine Institute, laying the groundwork for contemporary vaccination programs across America.

The invention of modern vaccines can be primarily attributed to Louis Pasteur, the father of modern microbiology. While the method of vaccination discovered by Jenner was invaluable in cases of smallpox, most diseases do not have a relatively inert relative, such as cowpox. Thus, inoculation with a live virus as Jenner had demonstrated could lead to severe infection and death in patients, requiring the development of a safer alternative. To combat this obstacle, Pasteur, who previously had formalized and verified his hypothesis of germ theory in 1861, set about to create a vaccine that did not use live virus matter (Smith, 2012).

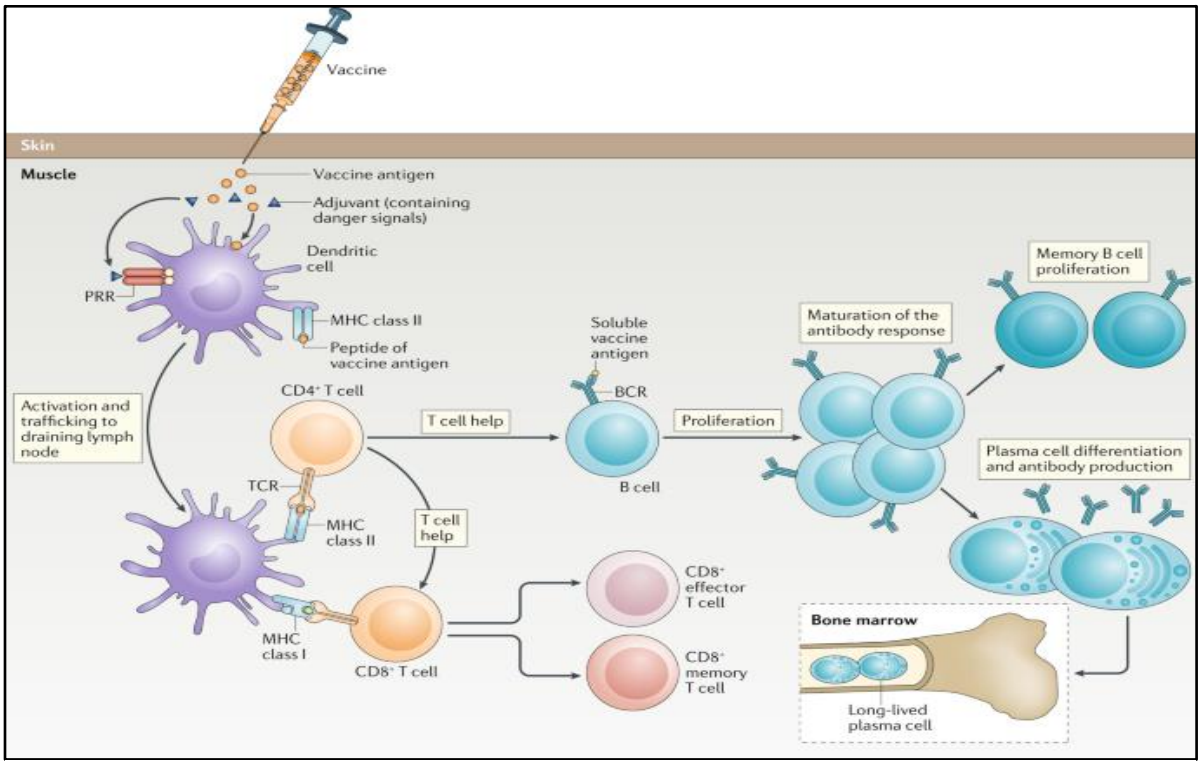
With the flaws of Jenner's vaccine in mind, Pasteur sought to create a more reproducible vaccine template that could treat various diseases, such as bubonic plague and typhus. Building on principles developed by Jenner and those in his wake, Pasteur hypothesized that many

illnesses could be prevented by "[diminishing] the microbe's virulence by changing the mode of culturing" (Smith, 2012, p. 6). Elaborating on Jean Joseph Toussaint's previous work, Pasteur attenuated chicken cholera by continuously exposing the culture to aerobic conditions for a couple of months. When packaged as a vaccine, this weakened bacteria could successfully immunize dogs against chicken cholera in 1880 (Smith, 2012). Pasteur believed that this method of vaccination was not merely successful due to coincidence, but stated that "this explanation [attenuation] will without doubt, become general and applied to all infectious diseases" (Smith, 2012, p. 6). After Pasteur's discovery, rapid innovation occurred, and various common vaccines were developed and produced on a widespread, laying the groundwork for immunization on a global scale in the 20th century.

Brief Overview of Vaccine Immunology

Since vaccines are a critical cornerstone of modern medicine, it is essential to understand their basic underlying functions. By definition, a vaccine is "an inactivated or attenuated pathogen or a component of a pathogen (nucleic acid, protein) that, when administered to a host, stimulates a protective response of the cells in the immune system" (Lahariya, 2016, p. 8). An alternative description of vaccines is "an immune-biological substance designed to produce specific protection against a given disease" (Lahariya, 2016, p. 8). Thus, vaccination is the process by which a person is administered a vaccine to develop resistance to a particular pathogen via acquired immunity (Plotkin et al., 2013). Individuals vaccinated receive the benefits of immunity without the risk of severe illness or death, thus significantly reducing morbidity and mortality overall. Figure 3 provides an overview of the immunological response generated by most vaccines.

Figure 3.
General Overview of Vaccine-Induced Immune Response



Note. This diagram provides a basic overview of vaccine-induced immunological response. From "A guide to vaccinology: From basic principles to new developments," by A. Pollard and E. Bijker, 2021, *Nature Reviews Immunology*, *21*(2), p. 88.

How Do Vaccines Work?

While the desired result of all vaccination methods may be the same, preventing infectious disease, many different routes exist to get to this objective. Various vaccine classes exist, each requiring unique synthesis methods and serving a specific function. Live bacterial vaccines, such as Pasteur's chicken cholera inoculation, are made through multiple rounds of *in vitro* culturing and usually only require one dose to be effective (Burrel et al., 2017). Inactivated vaccines are made of dead viruses whose genetic material has been destroyed by physical or chemical agents. While technically not virally active, these virus particles trigger an immune response that may require a multiple-shot regimen to achieve optimal immunity (Lahariya,

2016). Other common vaccines fall into two categories: viral-vectored (recombinant) and mRNA.

Viral-vector vaccines take advantage of modern recombinant technology. By utilizing specific genomic sequences, vector vaccines "[allow] the expression of viral epitopes on the surface of non-pathogenic bacteria" (Burrel et al., 2017, p. 160). Thus, viral-vector vaccines utilize a harmless virus to bring in critical instructions vital to antigen creation (Burrel et al., 2017). The most recent vaccine type invented is derived from mRNA. Utilizing the protein translation faculties of the recipient, mRNA vaccines expose the body to a segment of a viral genome. Intracellular machinery picks up the genomic data, producing precise epitopes of the virus in question and allowing a specific antibody response without any systemic viral presence.

Immunization Schedules

In addition to having various classes, vaccines also are administered according to experimentally-derived immunization schedules. Variations among immunization schedules serve two purposes: First, to provide immunity against a particular disease without the individuals incurring the effects of the disease. Second, to utilize spaced inoculation as a method of optimizing antibody response. With different vaccine classes, the time of inoculation is varied, with multiple doses required in many common vaccines.

Regarding the first objective, vaccines effectively expose individuals to an antigen, initiating an immune response. In the case of most common vaccines, antigens from the weakened virus direct the adaptive immune system to produce specific antibodies (Iwasaki & Omer, 2020). In turn, the vaccinated individual develops immunity to the wild-type virus or bacteria without contracting the illness. In regards to the second objective, particular immunization schedules have immense importance in providing long-lasting protection to the

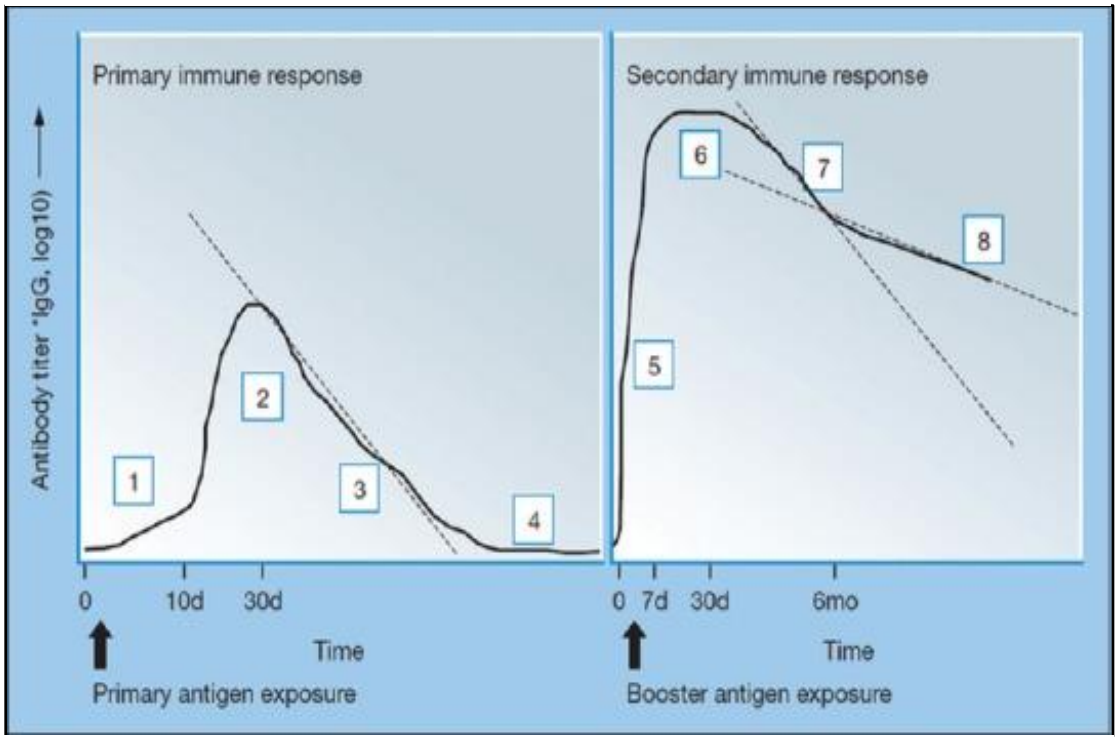
vaccinated individual. When receiving a vaccination course, such as during measles-mumps-rubella (MMR) and diphtheria-tetanus-pertussis (DTap) inoculation, doses are administered at various dates following the initial exposure to maximize immune response. More specifically, the booster shot is given to an individual once they reach peak antibody response, usually after three to four weeks (Lahariya, 2016). As Figure 4 demonstrates, booster shots at this point induce an even greater antibody response due to the presence of memory cells, leading to more robust and longer-lasting immunity. In turn, at the completion of the immunization schedule, a patient will have developed powerful protection against previously deadly diseases that are effective long-term. In the case of the MMR vaccine, for example, health officials generally recognize that the vaccine provides protection for a lifetime. Thus, one can easily see the benefit of such medical treatment if made widespread and accessible to the general public.

Components of Successful Modern Vaccination Programs

Herd Immunity

The most potent and direct effect of an individual getting vaccinated is robust and long-lasting immunity. However, the implications of their vaccination also play a role in maintaining the health of the community. In addition to being protected directly through inoculation, an individual in a community with high vaccine uptake has indirect protection through herd immunity. Herd immunity can be defined as “protection from an infectious disease as a result of living in a community where a large number of people are vaccinated against that disease” (National Cancer Institute, 2011, para. 1). With enough of a given population vaccinated, indirect protection is provided to community members who cannot be inoculated due to being immunocompromised or allergic to certain vaccine ingredients (Rodrigues & Plotkin, 2020).

Figure 4.
Primary and Secondary Antigen Exposure



Note. This diagram demonstrates the significantly larger immune response generated from vaccine boosters. From "Vaccine epidemiology: A review," by C. Lahariya, 2016, *Journal of Family Medicine and Primary Care*, *5*(1), p. 8.

Additionally, the uncontrolled spread of a disease does not occur, as not enough viable human reservoirs are present.

The number of individuals required to be vaccinated to achieve herd immunity depends on a disease's reproductive number, R_O, which describes how many people one infected individual can infect (Rodrigues & Plotkin, 2020). A pathogen's R_O is crucial in determining necessary vaccine coverage, as a higher reproductive number indicates a higher percentage of the population must be immune to eliminate community spread. R_O varies widely among common infectious diseases, from 1-1.25 for seasonal influenza, to 12-18 for measles (Biggerstaff et al., 2014). Accordingly, approximately 90-100% of the population must be immunized against

measles to prevent outbreaks, while mumps only requires ~60% coverage to eliminate community spread.

Applications of Herd Immunity

Herd immunity is a crucial component of successful vaccination programs since these initiatives rely on a certain percentage of the population being inoculated against the particular pathogen in question. Ideally, the desired goal of any vaccination program is the complete eradication of the pathogen (Andre et al., 2008). Virus eradication occurs when widespread vaccination against a disease is prevalent enough to prevent transmission from hosts and potential environmental reservoirs. In this scenario, the pathogen will not re-emerge unless the disease is reintroduced into the human population, either accidentally or intentionally. While total eradication may be the archetypal goal of modern vaccination programs, with programs such as the Global Polio Eradication Initiative (GPEI) being a prime example, past efforts have shown this to be an improbable outcome in most cases. Smallpox is the only disease that has been eradicated due to vaccination efforts, with the World Health Organization declaring the virus eliminated from the population in 1980 (Andre et al., 2008). Thus, smallpox vaccination is no longer part of standard immunization procedures due to no remaining pathogenic reservoirs. Since disease eradication is not an achievable goal in most cases, other objectives can be attained with similar effects on the overall community.

While eradication of most infectious diseases is not feasible under normal circumstances, virtual elimination from the population exists through the prevention of community spread. Locally, pathogens can be regionally eliminated without global eradication, as is the case with the prevalence of polio. A critical component of pathogen elimination for most infectious diseases is a specific percentage of vaccine coverage among a given population. While many

vaccines, such as DTap, meet this critical threshold, pockets of unvaccinated individuals remain, leaving room for the reintroduction of a pathogen with only a slight decrease in overall vaccination coverage.

Societal Benefits Due to Widespread Vaccination

While the choice to vaccinate oneself or one's children may seem like a solely personal medical decision at first glance, the decision to get vaccinated has a tremendous effect on society as a whole. According to the current scholarship, approximately 103,000,000 deaths due to common ailments have been prevented among the pediatric population since the turn of the 20th century (Iwasaki & Omer, 2020). Smallpox, a disease completely eradicated in 1980 due to widespread vaccination campaigns funded by the World Health Organization, killed an estimated 300,000,000 people in the 20th century. In 2009 alone, the CDC estimates that standard childhood immunization prevented approximately 20,000,000 cases of infectious disease and 40,000 deaths. Additionally, records indicate that there has been an ~90% decline in infectious disease prevalence in the United States since the onset of modern vaccination programs in the early 20th century (Rodrigues & Plotkin, 2020).

The benefits of standardized, society-wide vaccination are economically valuable as well. According to Rodrigues and Plotkin (2020), widespread immunization in the United States alone accounts for $69 billion in economic benefits. Vaccination against diseases such as pneumococcal meningitis prevents potential limb amputation, significantly reducing long-term morbidity from short-term infections. In the realm of smallpox, eradicating the disease through vaccination lowered healthcare costs by 1.5 billion dollars annually.

Overall, the benefits of widespread vaccination vastly outweigh the potential dangers. Despite the overwhelming evidence in favor of vaccination in most cases, a small but

considerable population in both the United States and around the globe remains largely hesitant to receive these life-saving drugs. While ideological motives may be involved, the most fundamental factor underlying these concerns are two forms of cognitive bias: loss aversion and omission bias.

What Causes Vaccine Hesitancy?

Despite the various benefits of widespread vaccination previously discussed, many individuals in the 21st century have become hesitant toward vaccination for themselves or their children. While many factors underlie objections to immunization, the groundwork for each concern stems from two cognitive biases: loss aversion and omission bias. In psychological terms, loss aversion is the belief that "losses of a fixed amount loom larger than gains of that same fixed amount; losing a fixed amount hurts more than the pleasure [benefits] derived from gaining that same fixed amount" (Kattan, 2009, p. 6). Medically speaking, loss aversion is prominent in patient decision-making, with some individuals believing that the negatives related to treatment, such as vaccination, are more significant in magnitude than the equally remarkable benefits.

Omission bias refers to "the tendency [of individuals] to perceive as worse and recall better, bad outcomes resulting from commissions compared to the same bad outcomes resulting from omissions" (Jiménez et al., 2020, p. 1). Concerning vaccines, omission bias plays a prominent role in hesitancy due to the widespread knowledge and exaggeration of worst-case scenarios, such as blood clots and Guillain-Barre syndrome. While such cases are uncommon, the attention given to adverse events disproportionately affects medical decision-making among vaccine-hesitant individuals. Thus, despite the risks involved, patients will not receive treatment even when provided positive and robust medical advice from their physician. In order to explore

these phenomena in the realm of vaccine hesitancy, an analysis of historical, religious, libertarian, and health-related objections will be conducted to demonstrate the connection of these factors with the underlying concepts of loss aversion and omission bias and their effects on individual health decisions.

Historical Objections

From the introduction of variolation in Europe to the present, objections to vaccination and immunization have ranged widely. In London, after the introduction of variolation in 1721, health officials were reluctant to allow this practice among the general populace. To test variolation's efficacy themselves, officials forced condemned prisoners to undergo the procedure, promising freedom if they survived (Flemming, 2020). Hesitancy against variolation also came from the frequent misdiagnoses of smallpox among poorly trained physicians. Mistaking cowpox for smallpox, physicians would not variolate patients because they believed they already had immunity. Thus, patients thought they were immune and would subsequently become infected, usually by variolated individuals. This common occurrence led to a widely-held belief that variolation caused smallpox infection rather than prevented it (Riedel, 2005). Additionally, concerns lingered about contracting other diseases during the procedure, as infection from medical procedures was common at the time.

Vaccination received immediate criticism among the medical community at the time of its discovery. In 1797, Jenner presented his revolutionary findings to the Royal Society, who promptly rejected the results, citing insufficient evidence and unforeseen risks that may be involved. Sentiment against vaccination became demonstrably present in the British population as the introduction of the British Compulsory Vaccination Act against smallpox brought widespread rioting (Nuwarda et al., 2022). This societal unrest resulted from uneasiness among

both scientists and the public about the restriction of personal liberties and forced compliance, as many thought vaccination could be deadly.

In the United States, hesitancy against variolation and vaccination has been present since the nation's founding. In 1721, Reverend Cotton Mather and Dr. Zabdiel Boylston made variolation famous in the American colonies (Riedel, 2005). During a smallpox epidemic in Boston, the two started a variolation program, reducing the fatality rate of inoculated individuals to 2%, much lower than the estimated 14% fatality rate of those who declined the treatment. Despite the remarkable success of the program, Mather and Boylston suffered from public controversy, with a bomb being thrown in Mather's house during the height of the outbreak.

Historical sentiment against variolation and vaccination underlies the hesitancy present in modern society. Much like the residents of Boston during the smallpox epidemic, current opposition to the practice is based mainly on the same assumptions, such as loss of personal liberty and medical choice.

Current Religious Objections

The most common objection to vaccination noted by researchers is rooted in religiously held convictions (Kibongani Volet et al., 2022). According to Williams and Leary (2019), vaccine hesitancy among all religious traditions hovers at approximately 25%, with no statistically significant difference among groups. While traditionally, major religions have supported vaccination and encouraged fellow believers to get vaccinated for the sake of others, many subsects of these significant religions hold opposing views to the mainstream. For example, Christian missionaries were influential in spreading Western medicine and vaccines to Sub-Saharan Africa. Prominent physicians such as David Livingstone, a congregationalist, made significant progress in developing vaccines against trypanosomes such as *Trypanosoma brucei*

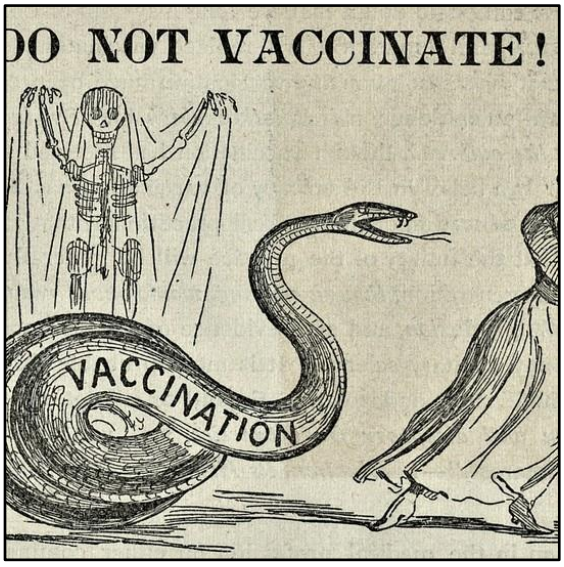
(Barrett & Giordani, 2016). Despite the remarkable progress in immunology attributed to men such as Livingstone, many in the congregationalist tradition, particularly the Amish, are opposed to vaccination in modern times. Thus, objections underlying vaccine hesitancy in these sects must be explored.

Influence of Religious Leaders

While exhaustive research has not been conducted on the impact of religious leaders on their congregations' vaccine acceptance, anecdotal evidence does indicate that it plays a role. For example, a 2013 measles outbreak in Texas occurred because of a pastor's sermons against childhood vaccination. No one was made seriously ill in this local outbreak, but the incident illustrates how influential a religious leader can be on their congregation (William & Leary, 2019).

On the affirmative side, studies have been conducted in the past noting the positive influence religious leaders can have on congregational health habits. In a study conducted in Nigeria, researchers indicated that promoting vaccine acceptance among religious leaders increased the odds of subsequent vaccination by 400% (Nasiru et al., 2012). In the United States, church attendants in Atlanta were noted to be more inclined toward influenza vaccination if negative attitudes toward the vaccine were not present in the congregation (Boggavarapu et al., 2014). While this research is not exhaustive, positive correlations can

Figure 5.
19th Century Anti-Vaccination Poster



Note. This image portrays vaccination as a deadly snake to be avoided. From *The Atlantic*, by The Historical Medical Library of the College of Physicians of Philadelphia, 2015. https://www.theatlantic.com/health/archive/2015/07/victorian-anti-vaccinators-personal-belief-exemption/398321/

be extrapolated from information, demonstrating the importance of religious leaders in personal medical decisions.

Objections from the Islamic Community

Religious objections to vaccination, while being influenced by faith leaders as previously mentioned, primarily stem from the belief that vaccination violates core tenets of their religion. Muslims generally agree that vaccination is an essential aspect of helping their community (Kibongani Volet et al., 2022). However, significant objections do exist within the morals of Islam itself. The main factor undergirding hesitancy among Muslims is the addition of non-halal or porcine ingredients in common vaccines. In this scenario, Muslims see avoiding vaccination as a lesser evil, as their religious beliefs dictate that consuming these ingredients is a grave sin.

Objections to vaccination among Muslim populations also arise during times of fasting throughout the year. More specifically, Ramadan is a time when Muslims will not receive vaccinations, as some faithful interpret the command of "refraining from anything entering the body cavity" to include medicines as well as food and drink (Ali et al., 2021, p. 1). Thus, some studies indicate that during Ramadan, 60% of Muslims would refuse vaccination if offered. While this may not be an issue during routine vaccinations such as MMR or DTap, objections of this kind could prevent the onset of local epidemics in Muslim populations, leading to increased spread and injury (Kibongani Volet et al., 2022).

Libertarian Objections

While religious anxieties toward vaccination provide an immense obstacle to increased vaccine uptake in faith communities, objections to immunization in the United States mainly rest upon individualistic tendencies ingrained in the American psyche. In particular, aversion largely stems from a fundamentally libertarian outlook toward bodily autonomy (Butler & Sorell, 2022).

The libertarian argument can be summarized in the following thought: Mandatory vaccination violates multiple principles of self-ownership and thus cannot be supported, regardless of the medical benefits that may be conferred. Due to the rise of personal belief exemptions in the United States, this objection is worth noting.

The most common libertarian objection to vaccination stems from a perceived loss of self-ownership due to the compulsory nature of immunization programs (Butler & Sorell, 2022). According to prominent libertarian scholar Murray Rothbard, self-ownership forms the basis of bodily autonomy and is thus essential to maintaining liberty in society. In relation to vaccine hesitancy, libertarian objectors would rather lose the medical benefits provided by vaccination than forfeit their bodily autonomy.

Historic Discrimination and Vaccine Hesitancy

Libertarians also object to vaccination in part due to the history of governmental abuse in the area of medical experimentation. Among the African-American population in the United States, for example, libertarian objectives are highly prevalent, primarily due to the abuse conducted against minorities in the Tuskegee Syphilis experiment (Butler & Sorell, 2022). Due to the systemic discrimination perpetrated against Black Americans during the 19th and 20th centuries, vaccine hesitancy within this demographic is strikingly low. According to Cato Laurencin, during the height of the COVID-19 pandemic, African-Americans were twice as likely to refuse vaccination against SARS-CoV-2, with the primary reason cited as mistrust of governmental health authorities (Laurencin, 2021). The repercussions of widespread hesitancy in this community are profound, with African-Americans being 2.7 times more likely to die from COVID-19 than Caucasians of the same socioeconomic and age demographics.

Sources of Information

The advent of the internet has also contributed to libertarian objections to immunizations. Despite the tremendous benefits wrought by instant access to health information, a significant rise in false information on the internet, particularly during the recent COVID-19 pandemic, has led to a substantial increase in vaccine hesitancy in the United States. This is due primarily to the widespread dissemination of anecdotal stories about adverse side effects of vaccination, which have a disproportional impact on public opinion in this regard. According to a recent study conducted during the initial rollout of COVID-19 vaccines, over 55% of Americans surveyed expressed hesitation toward vaccination. Additionally, most of these study participants cited internet-based information as the leading reason behind their skepticism. One of the most common sources cited in favor of vaccine hesitancy is the United States Vaccine Adverse Event Reporting System (VAERS), which allows individuals to report symptoms experienced after receiving standard immunizations (Azarpanah et al., 2021). Vaccine-hesitant individuals believe that the prevalence of reported incidents after immunization justifies their objections, as consenting to vaccination would violate their bodily autonomy and potentially cause injury or death. Thus, individuals of this persuasion refuse vaccination as a means of maintaining self-ownership, believing the symptoms reported on databases such as the VAERS justify their decision.

Health Objections

Among factors underlying vaccine hesitancy, health objections provide a substantial argument against compulsory vaccination. In contrast to other hesitant groups previously mentioned, individuals with legitimate health objections do not fall into omission bias or loss aversion. For severe cases, such as immunocompromised individuals and those allergic to

vaccine ingredients, vaccination among other groups with high vaccine aversion is necessary to protect the vulnerable population. Thus, objections of this nature must be handled with great care and constitute a legitimate concern against immunization.

Major Themes

Underlying Themes

Vaccine hesitancy is an issue that stems from various social, religious, and political concerns. Despite the seemingly unrelated nature of the previously mentioned objections to vaccination, an underlying theme of loss aversion and omission bias is evident. From the onset of modern vaccination technology in Europe and the United States, omission bias was demonstrably present. After variolation was introduced to the British medical community, the practice was almost instantly met with fierce resistance. Previous attempts at producing inoculation methods similar to variolation were prominent at this time, with many physicians causing death due to inoculation with improper technique. Physicians sometimes kill or maim patients in a well-intended quest to produce new, safer inoculation procedures. Knowledge of botched inoculations was commonplace in England then, and when Jenner introduced vaccination, these fears were not alleviated. In response to the introduction of vaccines, the populace, including the Royal Society of Medicine, thought vaccination was too dangerous because of the improper inoculations performed in the past (Flemming, 2020). Thus, these vaccine-hesitant individuals let unsubstantiated claims about variolation influence their opinions about a new and revolutionary medical technique.

Note about Justifiable Vaccine Hesitancy

Before discussing cognitive biases associated with vaccine hesitancy, an important note should be made about instances where this phenomenon is justifiable and necessary. One prominent

example where vaccine hesitancy would be warranted is actually the case of Jenner's experiments. As previously mentioned, Jenner experimented on James Phipps, an eight-year-old boy, by injecting him with a potentially fatal disease without the consent of Phipps' parents. In addition to Jenner, Benjamin Jesty is known to have deliberately infected his entire family with smallpox to prevent future infection without knowing whether the procedure would be successful (Riedel, 2005). As these extreme examples are meant to note, vaccine hesitancy is entirely reasonable when the vaccine has not been extensively tested in animal and human models before administration. In the case of Jenner and Jesty, the lack of research standards makes what were revolutionary discoveries entirely unethical according to modern standards. Thus, when discussing biases underlying vaccine hesitancy, it is essential to note that this refers specifically to aversion toward vaccines that are well-tested and documented as clinically safe and efficacious.

Response to Religious Objections

Loss aversion among religious populations with vaccine hesitancy seems more prominent than in other vaccine-hesitant groups. According to William and Leary (2019), individuals with religious objections to vaccination would instead follow the rhetoric of their pastor or spiritual leader, even if the advice given is not medically sound. Some congregation members may find it more reasonable to risk severe illness and death than abandon religious obligations. Furthermore, individuals in faith communities with charismatic and dominating religious leaders could fear disappointing their appointed spiritual counselor and thus refuse vaccination if it is against the congregation's will. Therefore, this pastoral effect can profoundly impact vaccine uptake in these communities.

Response to Libertarian Objections

Libertarian objections to vaccination are particularly prone to loss aversion and omission bias. Like their religious counterparts, vaccine-hesitant individuals in this demographic would rather risk their health and well-being than potentially give up perceived self-ownership (Butler & Sorell, 2022). While libertarian objections may seem like stalwart reasons to refuse immunization, the principles espoused by these groups contradict core libertarian teaching. For instance, Rothbardian libertarianism maintains non-aggression as a core principle in its ideology. Refusing standard vaccinations can violate the non-aggression principle, as the offending party willingly refused a treatment that would prevent future harm to others. When viewed from this perspective, vaccine hesitancy can be viewed as a fundamentally anti-libertarian position. Butler and Sorell (2022) also noted that many prominent Rothbardian scholars favor compulsory vaccination to prevent unintentional violations of personal liberty.

While an exposition of Rothbardian libertarianism may seem out of place in a discussion about vaccine hesitancy, the idea is vital for understanding the nature of libertarian objections to vaccination. In particular, it is interesting to note that in refusing standard vaccinations, libertarians are actually omitting a key principle of their ideology, contradicting a fundamental element of libertarianism in favor of another. While the right of self-ownership is paramount in maintaining a free society, this comes with an implied obligation to protect one's neighbor (Butler & Sorell, 2022). Thus, vaccine-hesitant individuals of this persuasion suffer from omission bias by ignoring an essential aspect of their own ideology while emphasizing another, contrary to the actual authorities in the field.

Vaccination as a Self-Defeating Achievement

An important note must be made about the self-defeating nature of widespread vaccination. In contemporary society, vaccine hesitancy has become an issue partly because of the lack of disease present among the population (Kumar et al., 2016). Since illnesses such as measles are not widely present among the general population, individuals can fail to understand the importance of vaccination against these diseases. According to Ebrahimi et al. (2021), vaccine hesitancy can be partially attributed to a lack of perceived risk of infection. Due to the low prevalence of diseases such as mumps and rubella, vaccine-hesitant individuals tend to believe these vaccines are unnecessary or even imposing.

Importance of Reputable Sources

Propagation of reputable and accurate information regarding vaccination is vital in increasing vaccine uptake. In particular, health professionals should advise patients to avoid information gleaned from non-scholarly internet sources due to the lack of peer review and frequent exaggeration present. However, even the use of reputable sources can be utilized to propagate misinformation. According to Azarpanah et al. (2021), one of the primary sources of vaccine hesitancy on the internet comes from the CDC's VAERS. Information from VAERS contributed significantly to omission bias due to the large number of events reported. However, while vaccine-hesitant individuals may use the high prevalence of VAERS reporting as evidence for their cause, necessary details are omitted. For example, Azarpanah et al. (2021) noted that 94.5% of VAERS reports are mild and include erythema, fever, and injection site swelling. Additionally, it is essential to note that the proportional incident rate of adverse effects from vaccination is approximately 25.3 reports per one million people.

Potential Solutions

Since vaccine hesitancy is an issue obstructing the successful eradication of various preventable diseases, many potential solutions have been proposed. Extensive research has been conducted on the success of various methods of increasing vaccine uptake, but only two will be elaborated on extensively: Community-based solutions and governmental intervention.

Community-based solutions to vaccine hesitancy have been shown to be efficacious in raising vaccine uptake. In particular, Dube et al. (2015) noted that physician-patient interactions are essential avenues for relaying accurate information about vaccines. Previous studies indicate that the vaccine uptake rate in a patient population is related to vaccine hesitancy among physicians (Facciolá et al., 2019). Thus, the propagation of reputable information about vaccines is vital for increasing vaccine uptake. Additionally, Dube et al. (2015) note that client or family-based incentive programs have been shown to increase vaccine uptake and provide critical information about the safety of common vaccines. Studies also indicate that information pamphlets given to patients from third-party sources are related to increased vaccine uptake, but the underlying reason needs further research.

Governmental interventions have historically been the primary driving force behind increased vaccine uptake. Since the advent of modern vaccination programs, legislative proposals have been proposed to maintain high community vaccination levels. One legislative approach to increasing vaccine uptake is maintaining strict vaccination requirements before primary school (MacIntyre & Leask, 2003). Personal exemptions unrelated to health or substantial religious objections should be forbidden, as these have decreased vaccine uptake in states like California. Legislative bodies at both the federal and local levels should implement information campaigns around times when vaccination increases, such as before the school year,

to provide the general public with reputable information about the vaccines their children receive. Distribution of information around these times could potentially decrease the use of internet sources lacking peer-review or exhaustive research on the topics.

Overall, a combination of community-based and governmental solutions has the potential to increase vaccine uptake in hesitant communities. Since empirical studies demonstrate that vaccine uptake and lax vaccine exemption policies are highly correlated, particular focus should be given to maintaining strict vaccination standards at places such as primary schools and universities. Tightening vaccine exemption policies and promoting transparency between governmental bodies and the populace can significantly reduce vaccine hesitancy while maintaining individuals' integrity and rights.

Conclusion

Vaccination is one of the greatest medical achievements of the modern world. From the eradication of smallpox to the elimination of many once-deadly diseases, vaccines have greatly improved the living conditions of society. Despite the clear incentives for the widespread dissemination of vaccines worldwide, significant resistance toward these life-saving treatments remains throughout the global population. While many factors underlying vaccine hesitancy, a theme of loss aversion and omission bias is demonstrably present. An extensive analysis of the factors underlying vaccine hesitancy indicates that these biases are heavily ingrained in religious, historical, and libertarian objections. To combat vaccine hesitancy derived from these objections, community-based and governmental solutions are necessary to provide reputable sources for both physicians and the population. In particular, further research needs to be conducted into physician-patient interactions and their effect on vaccine uptake. Additionally, legislation is necessary for tightening exemption policies in areas with decreasing vaccine uptake rates, as this

is a possible remedy to counteract increasing hesitancy in certain areas. Overall, vaccine hesitancy is an issue that will continue to factor into public health policy for the foreseeable future and should be researched in earnest to improve community health outcomes and reduce preventable diseases.

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