THE IMPACT OF SOCIAL MORES ON VACCINE DEVELOPMENT AND DISTRIBUTION DURING PUBLIC HEALTH CRISES

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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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New medical technology can be difficult to market to a hesitant audience. Many people are concerned about the potential impacts of using synthetically created biological materials in human patients (El Karoui et al., 2019). The ongoing technical project, whose goal is to design a bioreactor to improve muscle tissue growth outside of the body (*ex vivo)* for future implantation, may be received by a hesitant audience if not properly marketed towards their belief systems. This project is being carried out under the advisement of Steven Caliari of both the Chemical and Biomedical Engineering departments and is being completed alongside fellow undergraduate biomedical engineering students Benedict Albergo, Curtis Creech, and Aparna Kola.

Novel vaccine technologies are currently facing a similar threat to their success (Chirumbolo, 2021)(Jacobson et al., 2016). The STS thesis examines how evolving social mores (*more-ays*), which are the values and morals a society considers important, impact the success of vaccine technology distribution during public health crises. In studying this topic, the desired outcome is to determine what social factors hold the most sway in technological diffusion to optimize future technologies to target these areas effectively. Though this issue is not identical to the technical project, further research regarding popular science, perspectives on bodily autonomy, and the ethics of growing human tissues in a lab may reveal how the products developed out of the technical project might be best presented to a potentially hesitant audience.

The STS research paper examines the link between evolving societal mores and the development and acceptance of vaccine technologies during public health crises. As the Covid-19 pandemic continues to spread, nearing endemic status, widespread hesitance to accept newer vaccine technology has hindered efforts to reach herd immunity (Hoffman, 2021b). Since the invention of the first true vaccine in response to Smallpox, scientists have had access to an ever-expanding toolbox of technologies to inoculate populations against diseases (The College of

Physicians of Philadelphia, n.d.). However, the implementation of these tools and the overall acceptance of the final products has been inconsistent. While most vaccinations that are developed are consistently effective and safe for public use, society's acceptance of the technologies fluctuate frequently.

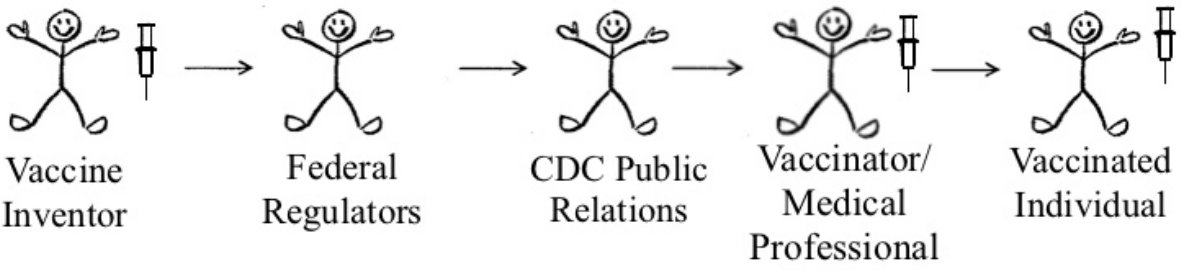

Figure 1: The Handoff Model for Vaccine Development. Handoff model utilized to show commercialization of vaccine technology. (Adapted by Roden (2021), Carlson).

As is often the case, history may provide a window into the causes of such patterns. By examining the social contexts surrounding a variety of public health crises with both good and bad outcomes, this project aims to determine how social mores influence the development and diffusion of vaccination technologies. Outbreaks of the plague in Italy from before the invention of vaccines will be studied as a baseline for human behavioral patterns within unmitigated pandemics (Marcus, 2021). Smallpox, influenza, and Covid-19 will be examined as case studies, as they all have varying levels of success in their outcomes. These historical case studies will then be contextualized within the Handoff model and the Technology and Social Relationships (TSR) model (Carlson, 2009). More specifically, the end user in the Handoff model, shown in Figure 1, will be considered as the central figure in the TSR model. Connecting these models will show how the actors involved in getting the vaccine from the bench to the clinic can reach patients effectively, and how those patients then influence their own social spheres with their acceptance of that same technology.

LIFE BEFORE VACCINES

ITALY, 1600s: A BASELINE FOR HUMAN BEHAVIOR

In “Revisiting the plague in the age of Galileo,” written in 2020, Hannah Marcus looks to an epidemic that struck Italy in the early modern era to make sense of the Covid-19 pandemic going on today. Marcus is an assistant professor at Harvard in the Department of History of Science and authored a book on medicine, science, and censorship in early modern Italy (Marcus, 2021). As Marcus examines the writings of Carlo M. Cipolla and Giulia Calvi on plague times in Italy, she draws extensive parallels between their struggles and our own pandemic. Marcus highlights the similarities between past and present plagues aptly by focusing on individual accounts that humanize our ancestors and demonstrate the struggles that remain relevant, even in a pandemic happening nearly four-hundred years later.

A striking opening line details a defiant mob of weapon-wielding churchgoers proudly disobeying local quarantine orders during a plague. Though the 2021 reader may immediately jump to conclusions about this anecdote, it is quickly revealed that this story is from 1630-1633 in Montelupo, Italy, a small town near Florence. Marcus effectively appeals to the common experiences of modern readers and makes it clear just how similar the past is to the present in a matter of sentences.

Marcus’s essay considers two accounts of these Italian plagues. The first, Cipolla’s, takes an empathetic view towards local civil servants and bureaucrats in their efforts to enforce safety measures on a resistant population. Calvi’s view, however, takes a personal look at the people living through these times who disobeyed regulations. The two accounts, though different in protagonists, paint a picture that is eerily like the current pandemic. Through studying these two

accounts, Marcus begs the question: How similar are all plagues, past and present, and how can we draw from these accounts to make sense of our current reality?

More resounding than any other line in Marcus's essay is this: "A common pathogen does not entail a comparable experience of epidemic" (p. 811). Calvi's protagonists are predominantly lower-class citizens, working paycheck to paycheck. For them, quarantining meant a loss of necessary income to survive. For the men, lying about not being sick so that they could go to work was normal unless their wages were less than what they would receive from the local government to stay home. The women, responsible for keeping homes running, became adept at treating medical issues on their own. There are accounts of women using hot iron rods to cauterize the boils caused by the plague, which is a well-documented and effective surgical technique for treating this disorder. In lieu of joining the isolation houses, they would remain home to care for others and keep their homes from being robbed or stolen.

These accounts of disobedience to local orders out of a necessity caused by financial hardship are directly mirrored in the COVID-19 pandemic. When staying home and staying safe are in direct contrast to one's financial security, it is easy to sympathize with the decision to disobey orders. Though the STS research paper is focusing on development and acceptance of vaccine technology, this essay serves well as a reminder. It is a great reminder that every individual has a stake in each situation, and that it is necessary to try to empathize with those we disagree with if we wish to uncover the truth behind their behaviors.

If there is one overarching takeaway from Marcus's essay, it is that there is nothing new under the sun. Marcus's narrative can place the reader in the shoes of a town struggling with a plague they didn't understand because everything these people went through is something the reader is likely going through today. However, by making the reader sympathize with the

disobedient citizens, it might encourage compassion in our modern crisis. It discourages the academic readers, who may not be at the same level of financial security as those who must disobey stay-at-home orders just to get by, from judging. History is always a good place to start when attempting to understand and find a solution in the present and Marcus's essay proves this well.

A BRIEF HISTORY OF VACCINES

As defined by Merriam-Webster, a vaccine is "a preparation that is administered (as by injection) to stimulate the body's immune response against a specific infectious agent or disease," (Merriam-Webster, n.d.). Though they were not called vaccines until 1882, the first vaccines were invented around the late 1700s by Edward Jenner. In 1796, Jenner exposed a young farm boy to cowpox, postulating that exposure to cowpox would inoculate the boy against smallpox (The College of Physicians of Philadelphia, n.d.). This attempt at inoculation was ultimately successful and would lay the groundwork for future research into vaccination technology as we know it today.

Shortly after this discovery, in 1813, the U.S. government established its first agency tasked with overseeing vaccination efforts. President Thomas Jefferson himself wrote a letter of thanks to Jenner for his discoveries and voiced his support for vaccine technology. Despite the existence of a rudimentary vaccination technique, smallpox still spread, albeit with a lower death toll for many groups. The incredible breakthroughs of Jenner and, later, Louis Pasteur, saved countless lives. The very existence of a vaccine, however, does not eradicate a disease. These vaccines must be successfully implemented on a wide enough scale to reach herd immunity. Therein lies the problem: How can scientists convince billions of people speaking countless languages with varying degrees of technical or scientific education to introduce a foreign

material into their bodies? To better address this issue, various methods of persuasion must be considered, as well as overarching legal methods such as mandated vaccinations.

Vaccination mandates are public health measures used to ensure enough of the population is protected against a disease for it to be effective in giving herd immunity. While these mandates are hotly debated today, they have been around for a long time. The first U.S. vaccination mandate was in 1855 and was imposed on the citizens of Cambridge, Massachusetts. This mandate was heavily litigated all the way to the Supreme Court. In Jacobson v. Massachusetts, 1905, SCOTUS upheld this mandate, citing the police powers given to states, and indicating that some personal liberties may need to be overridden in the cases of significant public health concerns (The College of Physicians of Philadelphia, n.d.). A similar case from Texas in 1922 was dismissed on these same grounds. These legal precedents have been the norm for the past hundred years. While there are nuances to the legality of mandates, such as in the case of private employers establishing these rules, the Jacobson ruling has acted as a precedent in mandate cases ever since its decision (Khalid, 2021).

ORIGINS OF ANTI-VACCINATION EFFORTS

Anti-vaccination efforts have been around since the invention of the first vaccine. The first meeting of the anti-vaccination league in New York City took place in 1882, shortly after vaccination spread through the country (The College of Physicians of Philadelphia, n.d.). The major arguments against vaccination are the same today as they were one hundred years ago. Some groups argue that vaccines are against the natural order or the will of a higher religious power. Others argue that mandating vaccines is a violation of civil liberties and personal freedoms (Wolfe & Sharp, 2002). There is also a vocal minority of parents who oppose childhood vaccinations, largely incited by a discredited paper from 1998 that linked the measles,

mumps, and rubella (MMR) vaccine with autism (Pew Research, 2017). While these arguments have not succeeded in preventing large scale mandates, they have led to many instances of exemption policies, whereby people with conscientious or religious objections to vaccines may pursue exempt status to avoid these mandates (National Conference of State Legislatures, 2022).

During the Covid-19 pandemic, many anti-vaccination arguments arose from widespread misinformation. Some extreme arguments posited that the vaccines were somehow linked to 5G cellular networks nationwide, while others believe that the entire pandemic is a conspiracy, so any treatments for it must be suspicious as well. Some more grounded theories are related to severity of vaccination complications and their likelihood to cause death, though the vaccine itself has been proven safe many times over (Loomba et al., 2021). Exposure to this misinformation from various forms of media was shown to have a correlation with decreased likelihood to accept the vaccine, per a 2021 study by Loomba et al. A larger problem connected to this issue is the widespread availability of misinformation on social media and basic search engines. Because everyone went online during the pandemic and relied on the internet for updates, misinformation sneaking into the mainstream sources had tangible impacts on people who could not validate information themselves or could not rely on peers to inform them. Vaccine misinformation and anti-vaccination efforts have hindered many public vaccination campaigns, and they need to be better understood to determine how to effectively communicate with people who may hold these beliefs currently.

VACCINATION TODAY

Today, vaccines are a normal part of life. You begin your first series of vaccines shortly after birth and continue getting boosters for most of your life. This has led to the eradication of many diseases, even within the last generation (CDC, 2020). Yearly flu shots are considered

normal, albeit forgotten by many. With the Covid-19 pandemic, vaccines have become a topic of conversation for many. They have so deeply integrated with our everyday life that younger generations make jokes on Twitter, comparing what vaccine brands people received and making memes about the less popular options.

In order to attend public schools, there are vaccine requirements as well. These are well-established rules and are widely followed by most people (Pew Research, 2017). However, Covid-19 vaccination requirements have been hotly debated and disobeyed, potentially due to misinformation and rampant fearmongering from the media. Despite this, vaccines are known to be one of the most effective ways to quell the spread of infectious diseases (CDC, 2021d). Countless vaccines are in development, with development occurring at a quicker pace than ever due to breakthroughs in medical technology. A key challenge for these researchers moving forward, however, will be convincing an increasingly cautious and mistrusting public to put their faith into vaccines whose technology becomes even more difficult to comprehend every year (Kennedy et al., 2022). To better appreciate the challenge ahead of these scientists, a few key cases of historical health crises might be studied to illuminate patterns in human behavior over time.

CASE STUDIES

SMALLPOX

Smallpox is an infectious disease characterized by fever and distinct skin rashes. Before the invention of its vaccine, 30% of those infected would die, and those who lived were often left with telltale scars on their skin where the rashes had appeared. Historians believe that smallpox has been around for at least 3,000 years, but there have not been any isolated natural cases of smallpox in the U.S. since 1977 and no major breakouts since 1949. The eradication of smallpox

has been attributed to the successful invention, dissemination, and acceptance of the smallpox vaccine (Niederhuber, 2014).

The initial smallpox vaccine, however, was not accepted by all with open arms. Many community members, doctors and religious adherents included, were concerned about the impacts of introducing cow-based biological material into humans. Benjamin Waterhouse, a Harvard physician who sought to introduce the vaccine to his community in Massachusetts, attempted to convince his neighbors in many ways. He even went so far as writing a piece in defense of cows, painting them as honorable and cleanly creatures that have always been helpful to humankind. Ultimately, a public campaign to offer free vaccines to the inhabitants of Milton, MA resulted in 300 vaccinations. These same public officials then decided to go even further and perform a public demonstration with local boys who'd been vaccinated previously. They exposed the vaccinated boys to smallpox and confined them to their houses for 15 days. When the time was up, none of them had contracted the virus. This act bolstered confidence in the vaccine and demonstrated that the officials trusted the treatment as well (Wendt, 2015).

As the vaccine spread and contributed to the decline of smallpox cases, some in the public grew to question its continued necessity. This is an example of a public health measure being harmed by its own success; because the vaccine worked it made the crisis seem less serious, which made the vaccine itself seem less necessary in turn (Schwartz, 2012). A combination of this pattern and the fledgling nature of the vaccine production industry likely led to the delay in full eradication of smallpox. Dedicated global efforts in the mid-20th century, however, led to its official eradication globally in 1977 (CDC, 2021a).

INFLUENZA – PAST AND PRESENT

Influenza (flu), in all its nasty forms, is a respiratory illness that infects anywhere between 3-11% of the U.S. every year, depending on the virulence of the seasonal strain (CDC, 2021b). Despite the high risk of contracting any form of the flu every year, only 50-58% of people in the U.S. were estimated to get the flu shot in 2021, which is fairly consistent with previous years but lower than one might expect for an easy-to-find and free vaccine (CDC, 2021c).

There are a few possible contributing factors to this public complacency with the flu shot. Because the flu is so quick to mutate, the yearly flu shot only protects against the strains that are most likely to be active in each season. However, this does not cover all types of the flu and can lead to many instances of infections in vaccinated individuals, which might cause apprehension towards vaccinating in subsequent years. These anecdotal stories of friends or family members who were vaccinated and still got the flu are heard every year and may contribute to wider disregard for vaccination (LaVito, 2018).

An alternative explanation might be that the message to get your flu shot is so widely repeated by doctors and professionals that it becomes a bit of background noise and does not stand out or elicit any sort of emotional response that compels the listener to act. Every year, we become more removed from past outbreaks of influenza that left communities ravaged by illness. Th 1918 flu pandemic killed 675,000 people in the U.S. in just one year, with 100,000 dying in the month of October. This disease effectively lowered the average lifespan of U.S. adults by 12 years (Easton, 2019). With emotional distancing from the narratives around the flu and flu shots, many may not see the necessity or the urgency for yearly flu vaccines.

COVID-19

Coronavirus disease 2019 (Covid-19) has killed over three million people worldwide since the outbreak of the disease began in 2019 (WHO, n.d.). It reached pandemic status in early 2020 and is still spreading as of March 2022. With new long-term complications for those who survive the infection being reported every day, reducing transmission and protecting oneself against the virus is paramount. Vaccines based in newer mRNA technology were rapidly developed and approved for emergency use by the FDA within the year that Covid-19 reached pandemic status. As of March 25, 2022, 65% of the U.S. population are fully vaccinated while only 29% are vaccinated and have received a booster shot of the vaccine (The New York Times, 2020).

This feat of scientific achievement, however, was overshadowed by misinformation, reduced faith in the CDC, and a political climate that made vaccinations a partisan issue (Tyson & Funk, 2022). Mixed messaging from the CDC, likely due to the rapidly changing nature of the virus, did not inspire confidence in their competency. Public denouncement of CDC leaders by former president Trump of the U.S. likely inspired mistrust and suspiciousness amongst his supporters (Kennedy et al., 2022). In Greeneville, Tennessee, these struggles with decisions surrounding vaccination are widespread and nuanced but may shed light on the thought processes of those who disagree with scientists.

A Small Town in Tennessee

The vaccines created to inoculate against Covid-19 have been met with more hesitancy than was expected. In a *New York Times* article Faith, freedom, fear: Rural America's Covid vaccine skeptics, journalist Jan Hoffman explores how the complex interplays between politics, religion, and personal freedoms influence vaccination rates in Greeneville, Tennessee. Hoffman

is a longtime journalist for *The New York Times* writing about behavioral health and health law and was curious as to why there was such a high resistance to the vaccine in many rural areas, so she spent time in Greeneville speaking to many community members at length in order to accurately tell this story. In late April 2021 Covid vaccines had just been made available to the entire adult population of the U.S., but many rural communities remained wary. While efforts to improve trust in the vaccine amongst Black and Latinx communities had been making positive strides, small pockets of rural America showed no signs of changing their minds, so Hoffman set out to understand this mentality by engaging with the Greeneville community.

Polling data provided in the article showed that predominantly Republican, Christian, and white communities such as Greeneville held some of the lowest vaccination rates in the country. A week spent interviewing the community showed Hoffman that their hesitancy was very nuanced. Many viewed the vaccine production process as rushed and worried it wouldn't be safe long-term. Ideals regarding bodily autonomy and governmental authority also played a role. Traditional beliefs surrounding self-sustenance and reliance on faith-based healing also impacted people's willingness to receive the vaccine.

Hoffman also discovered that many of the most trusted leaders of this community, pastors, were remaining tight-lipped about their own vaccination statuses and refrained from encouraging their congregations to get vaccinated, for fear of alienating listeners. Local physicians made dedicated efforts to dispel myths around the vaccine, but widespread hesitancy still remained. A recurring theme in this article is the lack of community members speaking openly with each other about their choices. Perhaps this, Hoffman seems to posit, is why the community failed to embrace the vaccine to the extent necessary to reach herd immunity.

Communities have incredible powers to impact the outcomes of public health crises. In many minority communities, religious leaders and trusted figures were able to convince constituents to trust the vaccine by being outspoken and engaging with the community on a personal level (Hoffman, 2021a; Pew Research Center, 2021). Here, Hoffman provides a bleak picture of what happens when trusted community leaders do not utilize their positions of power effectively. Without any sort of concerted effort by these leaders to impact the community's understanding of the new technologies, a culture of silence and mistrust formed instead.

A CHANGING SOCIETY

The world has changed more than anyone could know in the past 200 years. When the first vaccine was invented, the U.S. was still an infant country. Social structures were firm and unforgiving to everyone who was not a white male. Religion, though technically separate from the state, was still the pervasive ruler amongst a country which was founded by Puritans and religious zealots. Views regarding the relationship between personal liberties and duties to the country were just forming but were very distinct. Education was limited to few groups of people, and those without education were often in the charge of someone with education who would inform their choices regarding vaccination. The spread of information was much, much slower than it is today in the digital age. Access to information and disinformation, truth and lies, was limited by the time. Today, information is available with the click of a button. Lies can be spread without consequence. Widespread literacy has made information and opinions more accessible than ever. It would be fair to say that the landscape has changed significantly.

A community's mores are "centrally important and accepted folkways, and cultural norms that embody the fundamental moral views of a group," (Farlex Partner Medical Dictionary, 2012). These social mores have undergone drastic changes in the past 200 years.

Investigating these changes may provide a window into what views will impact vaccine technology acceptance in the future.

Per Pew Research center, the percent of Americans in a generation who identify as Christian has decreased from 85% from those born in 1928-1945 to 56% in those born from 1990-1996 (Pew Research Center, 2015). Along with this shift has been a shift in the government's policies in relation to religious issues. Secularization has occurred rapidly in the past 50 years. This can be seen clearly in the Supreme Court decisions in Roe v. Wade and Obergfell v. Hodges. Each of these events has indicated a nationwide shift away from traditional religious views, or at least their enforcement at a national level. Despite this, many still trust their religious officials and clergy members as authorities in society and would take their advice on medical issues (Pew Research Center, 2021).

From 1870 to 1980, the percent of all adults who were considered illiterate has dropped from 20% to 0.6% in America (NCES, n.d.). With the rise of education and the increase in the availability of materials to read, people have become more educated than ever. There are requirements to learn a baseline about each subject in school, though these have often failed many adults, especially after the "No Child Left Behind" project of 2002 (Lee, 2022). While we're more educated and can find information more easily, misinformation is just as easy to find and even harder to parse out. This means that future public health messaging must be clearer and more accessible to all people. Transparency, honesty, and easily understood language will be key to improving public health outcomes in the future.

WHAT WORKED, WHAT FAILED

TRUST

One main takeaway of this research is that trust is key for developing new technologies. With lack of trust in government officials to do what is right, and a lack of trust in scientists to act in the best interest of the public, technology cannot be effectively disseminated. Figure 1 on page 2 shows a model of the development of vaccines from benchtop to bedside. When there is no trust between the vaccinated individual at the end of the handoff and any one of the people in the chain before them, they may be likely to reject the technology. This rejection could then disrupt the other key part of a successful vaccine rollout: community engagement.

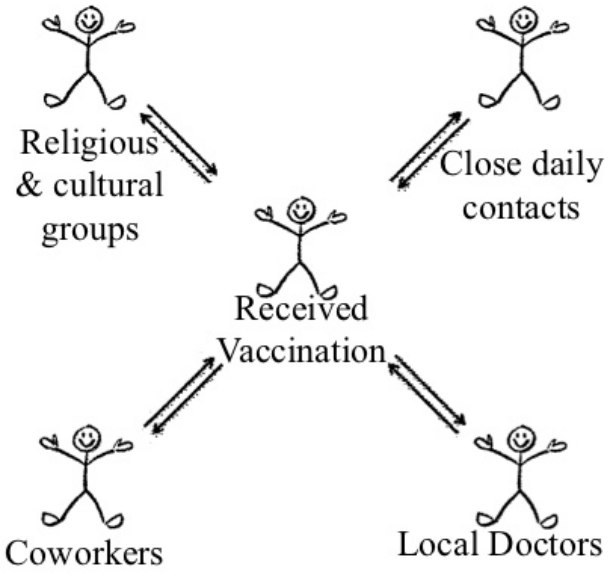

Figure 2: The Technology and Social Relationships model will illuminate how certain groups respond to vaccine technologies. (Adapted by Roden (2021), Carlson).

If the vaccinated individual from Figure 1 is the central user in Figure 2, their influence on their surroundings can be seen clearly. Key community members such as clergy and school leaders may prove to be even more effective than most if placed in the center of this model. Other potential trusted community leaders include city council members, rotary club leaders, tutors, or teachers. These people may have increased public confidence and, by showing that they trust the vaccine and its development process, they may influence their surrounding community members and family members positively.

RECOMMENDATIONS FOR THE FUTURE

The future of vaccine technology is bright. New treatments are being developed every single day. However, to successfully implement this technology, the sociopolitical climate of the target audience must be considered. By discovering what people hold the most credibility and trust amongst wary populations and engaging with those key figures to gain their support in these measures, public health responses may be improved. This strategy, alongside improved communication skills and government transparency, may help to bolster future responses to public health crises. In studying the social mores of the U.S. alongside its response to various public health crises, a pattern emerged that indicated the importance of gaining and leveraging trust in an increasingly mistrustful and dishonest world.

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